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# DOE/NASA CONTRACTOR REPORT

DOE/NASA CR-150747

## INSTALLATION PACKAGE FOR INTEGRATED PROGRAMMABLE ELECTRONIC CONTROLLER AND HYDRONIC SUBSYSTEM -- SOLAR HEATING AND COOLING

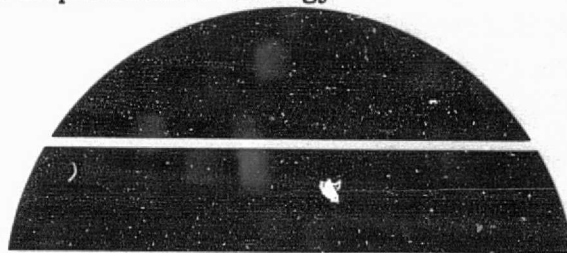
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For the U. S. Department of Energy



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INTEGRATED PROGRAMMABLE ELECTRONIC  
CONTROLLER AND HYDRONIC SUBSYSTEM - SOLAR  
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## Solar Energy

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16. ABSTRACT  This report contains the Installation, Operation, and Maintenance Manual and information on the power panel and programmable microprocessor, a hydronic solar pump system and a hydronic heating hot water pumping system. These systems are integrated into various configurations for usages in solar energy management, control and monitoring, lighting control, data logging and other solar related applications.			
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## 1. GENERAL INFORMATION

### 1.1 GENERAL DESCRIPTION - INTEGRATED PROGRAMMABLE ELECTRONIC CONTROLLER & HYDRONIC SUB-SYSTEM

The Sunkeeper I.P.E.C.H. subsystem is a completely assembled, piped, wired and tested package. It is designed to be used in large residential and small commercial solar heating applications. The package consists of three basic systems, a power panel and programmable micro-processor, a hydronic solar collection pumping system and a hydronic heating hot water pumping system.

The package requires only field connection of piping, power and sensor devices. It may be programmed to collect solar energy from the user's collector based on a number of user determined inputs such as solar insolation, date, time of day, outdoor ambient conditions, etc. In addition, it may be programmed to heat various zones of the user's facility as determined by user installed zone thermostats or to store collected solar energy in user supplied storage tanks. Once user supplied inputs are connected, sequence of operation, set-points, and priorities may be changed at will without the need for field wiring changes.

The user may, through the use of a compatible portable printer terminal, have access to the controller either on site or remotely by telephone modem. Access features include a 32 hour programable interval history file of user selected data, print-out of all inputs and outputs, location of control sequence in program, ability to edit program and program print-out. In addition, the controller may be connected to a remote master computer for data logging or master command, interrogation or program editing.

#### Built In Flexibility

Control sequence easily changed or modified  
by plant electrician or maintenance personnel

#### No Software Costs

User establishes his own control sequence and  
uses simplified commands to enter sequence  
into Sunkeeper - no initial or future software  
expenses.

#### Lower Overall Costs

No outside personnel required for installation,  
programming, or operation.

#### More Efficient

Uses less electrical power and is physically  
smaller than hard wired relay controllers.

More Reliable

All solid state construction - no moving parts that wear out or require alignment.

Future Expansion

Control sequence easily adapts to accept additional sensors or actuators as system expands.

Computer Compatability

Permits communications between Sunkeeper Control Unit and computer modems, printers or displays.

Data Logging

Monitors system performance and control operations and with printer terminal provides hard copy print-out of history of events.

25 Year Calendar/Clock

Accurate for 25 years, increments (seconds, minutes, days, etc.) can be included as part of user's control sequence.

• 1.2 CAPABILITIES

A powerful, non-erasable master program is stored in the Sunkeeper Control Unit's 8K of PROM memory. This factory supplied master control program allows the user to enter his particular control sequence program in the 16K of RAM memory. The combination of the master program and the user's control sequence provides the control for both the Sunkeeper Control Unit and the energy system being monitored.

The master program can perform the following basic mathematical operations:

- Addition of analog input values
- Subtraction of analog input values
- Comparison of analog input values

- Less than ( $<$ )

- Greater than ( $>$ )

- Equal to ( $=$ )

- Averaging of analog input values or % of "on" time of digital output, input or bit values.

In addition the master program can also solve the logic of a series of operations such as in the following statement:

If the value of A less the value of B is greater than C  
do a task

The user's control sequence is a specific logical operation that takes into consideration all the variables effecting his system (temperature, time, switch settings, etc.). When certain conditions are met, the control sequence uses the output lines to alter the operation of the system being monitored.

The clock is the only major component of the Sunkeeper Control Unit that is not controlled by either the master program or the user's control sequence. This calendar/clock has a 25 year life span. The clock is extremely accurate and provides discrete time increments of tenths of a second, seconds, minutes, hours, time of day, week, month and year. The clock automatically compensates for Leap Years and months having 31 days. It never needs to be adjusted as long as power is not lost for longer than two consecutive days. But even then, it is easily reset and will continue to run with the same accuracy. The clock increments (seconds, hours, days, etc.) can be used by the users control sequence for time clocking functions, step controlling functions, or to set time delays between energizing or de-energizing a series of items. (Refer to Sect. 3.5)

Another unique capability of the Sunkeeper Control Unit is the ability of the master program to perform data logging operations. This data logging feature permits the status of any combination of inputs or outputs (up to 16) to be sampled at selectable intervals. Upon request by the user, the log containing the averaged values of the monitored lines is printed out in a format usable by plant engineers or maintenance personnel.

As the user constructs, debugs or edits his control sequence the master program monitors the entries and, if incorrect procedures are attempted, prints out an error message that identifies the incorrect action. The user can also modify an existing control sequence without actually first destroying the old sequence. This permits the user to evaluate a new control sequence before making it permanent in his system.

The Sunkeeper Control Unit also permits both digital outputs and analog inputs to be disabled from the operating system and other values assigned to these lines. By use of terminal unit. This disable feature is especially useful when checking out new equipment added to an existing system or when servicing or troubleshooting a system that is suspected of improper operation.

The Sunkeeper Control Unit has a complete computer-like interface with provisions for selectable data transmission (baud) rates. This permits a wide variety of interfacing equipment for input/output operations. (computers, teletypewriters, CRTs, printers, etc.)

The I.P.E.C.H. subsystem is designed to pump water and control flow through any or all of eight solar collectors or hot water heating zones. The pumps and zone control valves of the subsystem are wired to the control panel. The Sunkeeper controller in the panel may be programmed to turn these "OFF" and "ON". The Sunkeeper controller will accept up to 32 digital inputs (switch closures) and 32 analog inputs. The basic I.P.E.C.H. subsystem requires the first 18 of a total of 32 digital outputs available are used to control the zone valves and pumps. The remaining 14 outputs may be wired to control user determined items such as relays, motorized valves, alarms, etc. These outputs are in the form of SPDT switch closures. Any

or all of the inputs may be used in programming to control all outputs. Any 16 of the inputs or outputs may be data logged.

### 1.3 FEATURES

The rugged solid state construction of the Sunkeeper Control Unit allows it to be installed in normal work areas. No special enclosure or environment is required. Even occasional water splashes or rain do not effect the controller operation. Also, it not effected by high humidity, high or low temperatures and it can operate in high dust levels.

The back up battery continues to power the calendar/clock and the RAM for up to two days if normal AC power is lost. During this battery powered period the Sunkeeper can not perform any control operation, but the clock timing and user's control sequence is not lost. This prevents temporary power losses from erasing the user's control sequence thus necessitating having to reload the complete sequence. The master control sequence can not be lost, damaged, or altered by extended power outages (less than 60 days) or even by incorrect programming or operator actions. The indestructible master control sequence can be changed or erased only at the Sunkeeper factory.

All inputs (32 analog and 32 digital) and outputs (32 digital) lines are optically isolated by the internal circuits. This isolation prevents high voltage transient spikes from damaging the processing circuits.

The 32 digital inputs accept on/off conditions that monitor the status of motor starters, valves, switches, door closures, alarms, thermostats, and other interlocks. The 32 analog inputs can be connected to detectors that monitor temperatures, pressures, light intensity flow rates, humidity or other control variables. Thermistor sensors produce reading directly in

degrees Farenheit. No conversion is needed. The 32 digital (on/off) outputs can be used to start or stop motors, open or close valves, and perform other functions in the control scheme.

The Sunkeeper Control Unit has plug-in connections for input and output control wiring. This permits the unit to be disconnected quickly and easily during initial hook-up and also for maintenance procedures.

Multiple Sunkeepers (up to 10 units) can be interconnected utilizing the standard ASCII procedure to produce more complex systems and also to permit a central communications station for all units.

The I.P.E.C.H. sub-assembly is a complete factory wired and tested package. All components are mounted on a structural steel frame. The control panel contains the Sunkeeper Controller, 4 triac relay boards, terminal strips, convenience outlet, transformer, motor starters and circuit breakers. The sub-system requires only field connections to user supplied power and solar and heating zone piping. User supplied sensor and digital input wiring may be connected to the terminal strips provided. In addition, user supplied controls such as valves, relays and motor starters may be wired to the terminal strips provided. User must supply control voltage power source for these additional items.

#### 1.4 Typical Sunkeeper Applications

While the Sunkeeper Control Unit can be configured in many applications, most usages can be classified under one of the following four major application headings:

1. Energy Management Systems
2. Control & Monitoring Applications
3. Lighting Control
4. Data Logging



## 1.5 SUBSYSTEM PERFORMANCE SPECIFICATIONS

### SUBSYSTEM ENVIRONMENT

TEMPERATURE: 40° to 100°F  
RELATIVE HUMIDITY: 5 - 95% non-condensing  
PRIMARY POWER: 117 ± 10%, single phase, two wire  
60 Hz 30 amp service

### HYDRONICS

#### COLLECTOR CIRCULATION SYSTEM

FLOW RATE: 15 gal./min.  
MAX PRESSURE: 30 PSI  
PRESSURE HEAD: 20 feet maximum

FLUID TEMPERATURE: 240°F  
PUMP DUTY CYCLE: 100%  
UP TO EIGHT (8) ELECTRICALLY VALVED PORTS FOR ARRAY  
CONTROL AT 3.3 Cv/VALVE

#### ZONE WATER SYSTEM

FLOW RATE: 40 GPM  
MAX PRESSURE: 30 PSI  
PRESSURE HEAD: 30 ft. max.  
FLUID TEMPERATURE: 240°F Max.  
PUMP DUTY CYCLE: 100%  
UP TO EIGHT (8) ELECTRICALLY VALVED PORTS FOR ZONE  
CONTROL AT 4.1 Cv/VALVE

#### COLLECTOR PANEL MANIFOLD VALVE MODULE

MAX. PRESSURE: 125 PSI  
VALVE ACTUATOR: 6 Watts @ 24VAC  
VALVE ACTUATION TIME: 10 Seconds  
MAX TEMPERATURE: 240°F  
PIPE SIZE: 3/4 inch Output, 1 1/2 inch Inlet

#### ZONE MANIFOLD VALVE MODULE

MAX. PRESSURE: 125 PSI  
VALVE ACTUATOR: 6 Watts @ 24VAC  
VALVE ACTUATION TIME: 10 Seconds  
MAX. TEMPERATURE: 240°F  
PIPE SIZE: 1 inch Output, 1 1/2 inch Inlet

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## AUXILIARY ENERGY SOURCE CIRCULATOR PUMP

CONTROL IS AVAILABLE FOR UP TO 1 HP PUMP

### PHYSICAL SIZE

SIZE: 32" x 4' x 6' Height  
SUBSYSTEM WEIGHT: Approximately 900 pounds

### DESIGN LIFE

DESIGN LIFE OF ALL SUBSYSTEM MODULES: 20 Years

### CONTROLLER

POWER: 117VAC  $\pm$  20%, 60 Hz, 25 Watts  
SIZE: 24.0" x 16.0" x 4.75"

### ANALOG INPUTS

THERMISTOR: Potentiometric measurement with pull  
up resistor ( $3K \Omega$ ) to +6.2V  
ANALOG: .0 to 6.2V.,  $Z_{in} > 3K$   
MANUFACTURES: Fenwal; or Precon

### SWITCH INPUTS

RIISING THRESHOLD: 9.2 - 15.5 Volts  
FALLING THRESHOLD: 1.75 - 7.3 Volts  
INPUT IMPEDANCE: 1.5K  
STATE DEFINITION: OPEN = GND = OFF  
LED INDICATOR WITH EACH INPUT

### DIGITAL OUTPUT

CURRENT CAPABILITY: 100 mA sink max.  
VOLTAGE: Clamped to +24V, -0.3V  
LED INDICATOR WITH EACH OUTPUT

### VOLTAGES (AVAILABLE FOR USER)

+5, +8, +24, +12 Volts Available On Connectors  
@ 250 mA Max. Each

## SECTION II INSTALLATION

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### 2.1 UNPACKING AND INSPECTION OF SUNKEEPER CONTROLLER

The Sunkeeper Control Unit is shipped in a durable box that will protect the unit from damage during normal handling. The Sunkeeper Controller is shipped separately from the I.P.E.C.H. package and must be field installed in the control panel.

#### NOTE

It is recommended that the shipping carton and the shock resistant foam packaging material be saved for use as a storage container or, in the event the unit has to be returned to the factory, as a shipping carton again.

Each Sunkeeper is shipped with six standard input/output ribbon cables and a 7th communications cable that is specifically configured to interface the user's terminal (TTY, printer, CRT) to the Sunkeeper. Four of the ribbon cables are terminated at one end with a 25 pin female connector and the other two cables have a male 25 pin connector at one end. These 6 ribbon cables have the other cable end wired to input/output terminals so that they can be connected to the load side of the control system.

#### NOTE

Be sure to check the equipment and accessories found in the shipping box against the invoice or bill of materials to ensure that the correct items were received.

After completely unpacking, a thorough inspection of all items should be made. In particular, check the Sunkeeper for obvious damage to the cabinet or for a cracked or broken display panel.

### 2.2 SITE REQUIREMENTS

The Sunkeeper operates in normal working environments. No special conditions are required, unless the temperature or humidity exceeds the units

wide ranges of 40 to 100°F or 5 to 95% humidity.

Therefore, while the Sunkeeper performs the control functions commonly only found in delicate computers, it can be installed directly in normal working areas. It's rugged, solid state construction can withstand the typical control room conditions because it is drip proof, vibration resistant, and immune to electrical "noise" (static).

The Sunkeeper is designed to be vertically mounted so that the seven interface cables route out of the bottom of the unit. The only restriction on the physical placement of the unit is that a normal air flow should be able to pass through the unit. (The Sunkeeper is located in control panel.

NOTE

Do not mount or stack items directly above or below an installed Sunkeeper Unit. These items may prevent the Sunkeeper from receiving the air flow normally used to cool the unit.

The Sunkeeper Control Unit requires a standard three prong ground 115 VAC power receptacle which has been provided in the control panel.

CAUTION

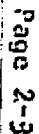
REFER TO SECTION 3 BEFORE PLUGGING IN POWER CORD

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2.3 CONNECTION OF INPUTS AND OUTPUTS

The recommended configuration for input and output connections is shown in Dwg. 1054-000. The ribbon cables are routed from the jacks on the Sunkeeper to one side of the terminal block. Each individual wire in the cable is separated, stripped, and attached to the corresponding terminal number on the block.

Tables 2-1 through 2-3 list the signals assigned to the individual wires in the ribbon cable connected to the input/output jacks.



The customer load side wiring connects to the other side of the terminal block. It is recommended that 18 gauge wire be used for this customer interface. This gauge is sufficient for wire lengths up to 1000 feet.

All 32 digital inputs and 32 analog inputs are prewired to terminal strips. Refer to wiring diagram Dwg. 1054 for identification of these items.

The first 18 trial outputs have been factory wired to control the zone valves and pumps. The balance of 14 trial outputs have been factory wired to terminal strips in the control panel. For identification of these items refer to wiring diagram Dwg. 1054-000.

TABLE 2-1  
ASSIGNMENT OF INPUT SIGNALS

Wire or Pin No.	Digital Inputs to Sunkeeper Connector JA	Digital Inputs to Sunkeeper Connector JB	Analog Inputs to Sunkeeper Connector JH	Analog Inputs to Sunkeeper Connector JJ
1	IN1	IN17	A1	A17
2	IN2	IN18	A2	A18
3	IN3	IN19	A3	A19
4	IN4	IN20	A4	A20
5	IN5	IN21	A5	A21
6	IN6	IN22	A6	A22
7	IN7	IN23	A7	A23
8	IN8	IN24	A8	A24
9	IN9	IN25	A9	A25
10	IN10	IN26	A10	A26
11	IN11	IN27	A11	A27
12	IN12	IN28	A12	A28
13	IN13	IN29	A13	A29
14	IN14	IN30	A14	A30
15	IN15	IN31	A15	A31
16	IN16	IN32	A16	A32
17	+24V	+24V	+24V	+24V
18	+24V	+24V	+24V	+24V
19	+24V	+24V	+24V	+24V
20	+24V	+24V	+24V	+24V
21	+24V	+24V	+24V	+24V
22	+24V	+24V	+24V	+24V
23	GND	GND	GND	GND
24	GND	GND	GND	GND
25	GND	GND	GND	GND

See Note

See Note

SEE NOTE

NOTE: +24V and GND are not inputs but are available at the designated connector pins for customer use.

TYPICAL CONNECTION CONFIGURATION

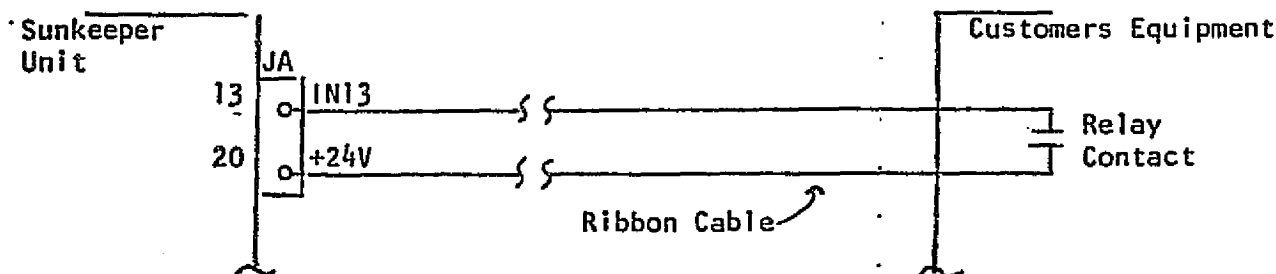


TABLE 2-2  
ASSIGNMENT OF OUTPUT SIGNALS

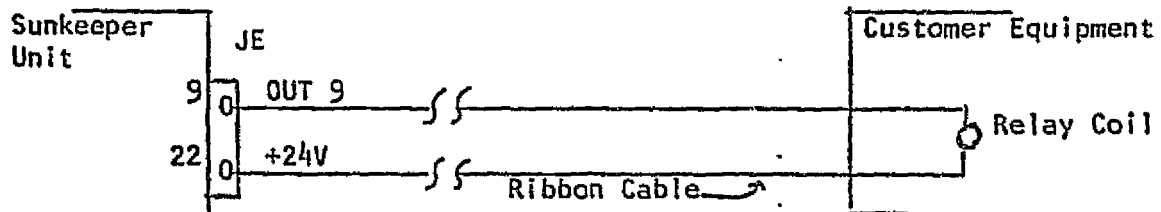
Wire or Pin No.	Digital Outputs from Sunkeeper Connector JE	Digital Outputs from Sunkeeper Connector JF
1	OUT1	OUT17
2	OUT2	OUT18
3	OUT3	OUT19
4	OUT4	OUT20
5	OUT5	OUT21
6	OUT6	OUT22
7	OUT7	OUT23
8	OUT8	OUT24
9	OUT9	OUT25
10	OUT10	OUT26
11	OUT11	OUT27
12	OUT12	OUT28
13	OUT13	OUT29
14	OUT14	OUT30
15	OUT15	OUT31
16	OUT16	OUT32
17	+5V	+5V
18	+5V	+5V
19	+8V	+8V
20	+8V	+8V
21	+24V	+24V
22	+24V	+24V
23	GND	GND
24	GND	GND
25	GND	GND

See Note

See Note

NOTE: +5V, +8V, +24V, and GND are not outputs but are available at the designated connector pins for customer use.

TYPICAL CONNECTION CONFIGURATION



CAUTION: The Sunkeeper can only supply a total of 250 ma. If requirements exceed this limit, an external power supply must be used.



TABLE 2-3

ASSIGNMENT OF INTERFACE SIGNALS

Wire or Pin No	Signals at Master EIA Connector. JC	Signals at Satellite EIA Connector JD
1	Chassis	Chassis
2	TDM (Output Or'ed)	TDF (Input)
3	RDM (Input)	RDF (Output)
4	RTSM (Output Or'ed)	RTSF (Input)
5	CTSM (Input)	CTSF (Output)
6	Not Used	Not Used
7	Signal Gnd.	Signal Gnd.
8	Not Used	Not Used
9	Not Used	Not Used
10	Not Used	Not Used
11	BS1	BS1
12	Not Used	Not Used
13	Not Used	Not Used
14	Not Used	Not Used
15	Not Used	Not Used
16	Not Used	Not Used
17	Not Used	Not Used
18	BS2	BS2

- NOTES: 1) Connector JC provides the interface between the Sunkeeper and the input/output terminal.
- 2) Connector JD is only used in multiple Sunkeeper configurations. In this daisy-chain installation, connector JD receives all signals applied to JC. Outputs from JC to JC are OR'ED in the first Sunkeeper and transmitted out JD to connector JC in the second controller, etc.

## 2.4 INSTALLATION CONNECTIONS

- 2.4.1 For installation dimensions of I.P.E.C.H. package refer to Dwg. 1061. A total of 18 piping connections are required. They consist of 8 - 1" male copper heating system supply zone connections, 8 - 3/4" male solar system supply zone connections, 1 - 1 1/2" female copper heating system common return connection and 1 - 1 1/2" female copper solar system common return connection. It is recommended that offsets in all these connections be made to eliminate excess loads being applied to the package piping due to thermal expansion. If vibration transmission is a concern, flexible connectors are recommended.

## 2.5 FIELD WIRING

- 2.5.1 1 1/2" diameter hole has been provided in the control panel to allow for electrical power connection. A 115V, 1 Phase, 60 Hz, 30 Amp service is required. Each package contains a 1/2 HP and a 1 HP pump motor. Both motors may have occasion to start simultaneously.
- 2.5.2 There are 32 digital inputs, 32 analog inputs and 14 digital outputs available in the control panel. These items have been factory wired to terminal strips. Refer to wiring diagram Dwg. 1054 for location and identification. Some or all of these items as determined by the user must be field wired.
- 2.5.3 All field wiring shall comply with the National Electric Code and all state and local codes.

### 3.1 LOCATION OF INDICATORS

The locations of the front panel indicators are shown in Figure 3-1. The description and function of these display panel items is given in Table 3-1.

### 3.2 INITIAL START-UP PROCEDURES

These procedures are valid only for the first time a Sunkeeper is energized after receipt from the factory. To insure a successful start up, the following procedures should be performed in the exact order presented:

1. Disconnect all input and output cables connected to the Sunkeeper.
2. If connected, disconnect interface cable from terminal to Sunkeeper (at JD)
3. Plug Sunkeeper AC power cord into 115 VAC grounded outlet.
4. The following front panel indicators should illuminate:
  - a) Five power supply lights (11 through 15, Figure 3-1)
  - b) Timing (10, Figure 3-1) should blink on and off at one second rate.
  - c) RTS indicator (5, Figure 3-1)
5. If the correct indications are displayed proceed to Step 13. If indications are not as listed above, perform step 6.
6. Unplug the AC power cord and check the line fuse (25, Figure 3-1)
7. If correct rated fuse installed wait approximately five minutes then apply AC power again.
8. If the indications are still not correct, unplug the unit and unscrew the six screws that secure the front display panel.
9. After removing the display panel, gently push down on each of the 8 integrated circuits. This action insures that these circuits (the PROMS that contain the master control sequence) are seated

securely in their sockets.

10. With the display panel removed, check to see that the cable connector in the cable between the RAM and the main logic board is mated correctly.
11. Install the front panel, and plug in the Sunkeeper.
12. If the correct indications do not appear, unplug the unit and re-package the unit for return shipping to the factory.

#### NOTE

Refer to the Sales Agreement for complete shipping instructions.

13. Connect the interface cable only for the terminal into JD.

The Sunkeeper is now ready to accept commands from the terminal and to transmit data back to the terminal.

### 3.3 HOW TO ENTER COMMANDS

All communication between the Sunkeeper and the operator is via a teletypewriter\*or a CRT terminal. Commands and equipment status are presented in easy to understand English abbreviations. No complex, computer-like languages are used. \*(Texas instruments silent 745 or equal)

All commands are sent to the Sunkeeper by typing them on the terminal's keyboard. Responses from the Sunkeeper are presented on the video display or typed out on paper. All commands to the Sunkeeper are followed by a "Carriage Return" (CR) which indicates to the Sunkeeper that the command is completed. The unit does not process a command until the CR is entered (typed). As characters of a command are typed by the operator, they are displayed at the terminal. Whenever the Sunkeeper is ready to accept commands from the terminal, it types the character "R".

Most commands are a combination of capital letters and numbers. Only capital letters are allowed in alpha-numeric commands.

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Letters are produced in the standard typewriter method of holding down the SHIFT key while typing the letters. Remember to release the SHIFT key when numbers are being entered!

Most commands consist of a series of numbers which are entered separately by commas or spaces (SPACE BAR pressed for each space). If a series of sequential numbers are to be entered, the first and last number is entered, separated by a dash. For example, "5 - 8" is equivalent to "5,6,7,8". Also the slash symbol (/) is interpreted by the Sunkeeper as "all numbers which apply". For example, in specifying output lines, "/" has the meaning 1-32 because there are 32 output lines.

Spaces between letters and numbers in a command require the SPACE BAR be pressed to enter the correct command.

If during entering a command an incorrect character is typed, it can be erased by pressing the RUBOUT key one time for each incorrect character. Whole words or even complete command lines can be erased using the RUBOUT key. All data, back to the last CR, can be erased and re-entered without effecting the Sunkeeper.

No matter how incorrectly commands are entered, the master control sequence can not be damaged through improper terminal usage. Also, the master control sequence can detect incorrectly entered commands and notify the operator of his mistake. If anything about a command is incorrect, the Sunkeeper types an error message number followed by a question mark. Table 3-2 contains the list of error message numbers and their meanings. Using these descriptions you can re-enter the command correctly and then continue communicating with the Sunkeeper.

### 3.4 ADDRESSING SUNKEEPER UNITS

Each Sunkeeper Unit is assigned a unique four digit address code that must be used when initial communications with the unit are attempted. The correct way to address a Sunkeeper is as follows:

\$ N \_ \_ \_ \_

This command in English is entered in 5 steps:

1. Press Shift Key
2. Type \$ (ampersand key)
3. Type N
4. Type four character address code
5. Release Shift Key
6. Press Carriage Return key (CR)

After the address code is entered the Sunkeeper is ready to accept other commands.

All communications with a Sunkeeper unit must be preceded by its address code in this form, or the unit will not accept any commands from the operator.

7. Type Z & to clear all programming.
8. Re-enter code 9. Type Pu: should print pull.

### 3.5 SETTING CALENDAR/CLOCK

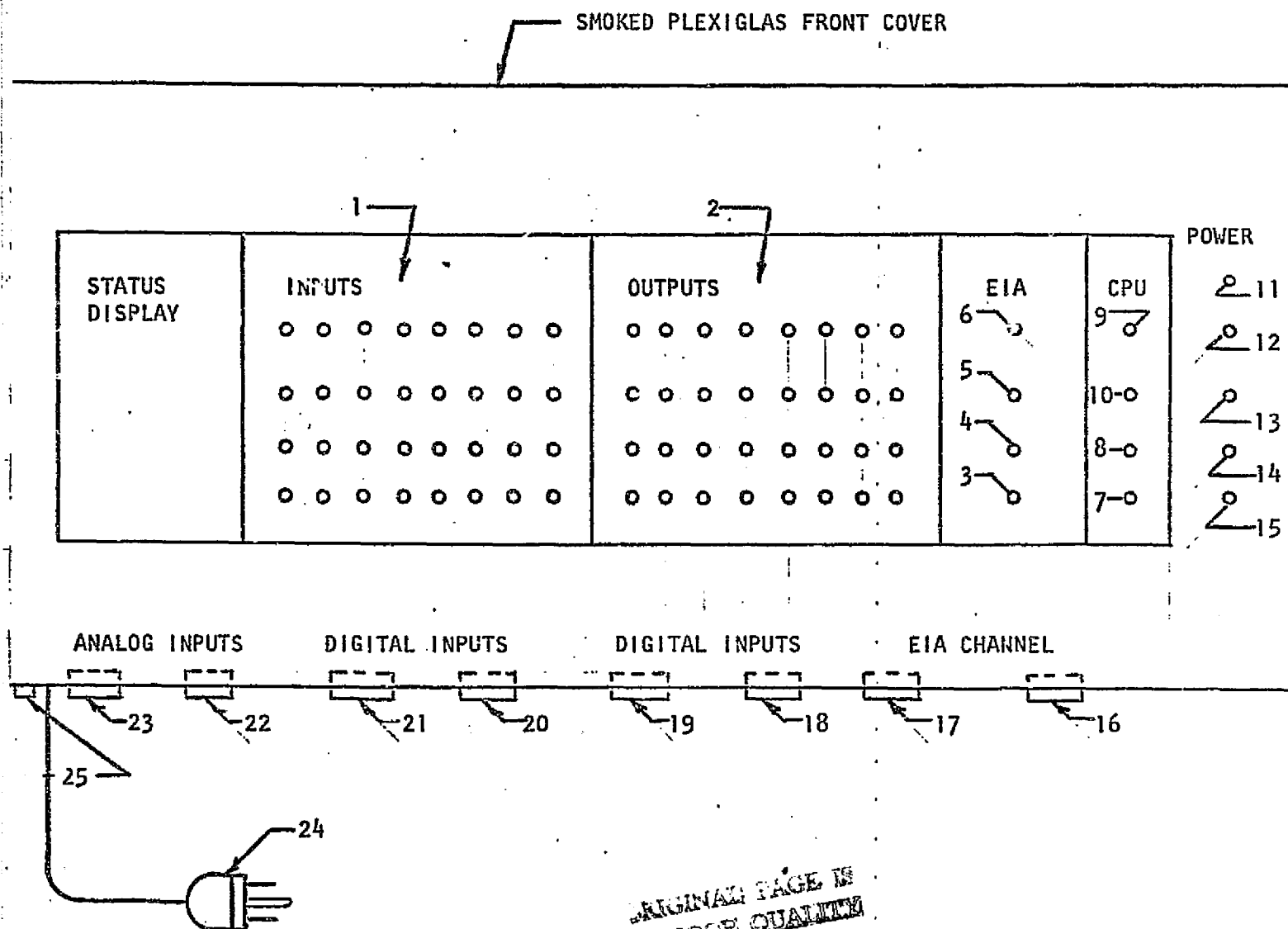
The following procedures describe the steps required to set the internal calendar/clock to the correct time and date. These procedures are applicable for new installations and to reset the time after a power failure of longer than two days.

1. Type correct address code: (\$ N four digit code (CR))
2. Type Print Time command: TI (Shift, TI, unshift, CR)
3. The printout will be seven, 3-digit groups of letters on a line.

There should be a space between each group of letters. If this is a new installation any combination of letters and numbers may appear

in these groups.

4. Type Set Time command: ST (shift, ST, unshift, CR)
5. After the Sunkeeper is ready, it prints out "R" the following seven time increments can be entered with the correct values: Year, Month, Date, Day of Week, Hour, Minute, Second. Refer to Figure 3-2 and enter these values.
6. To set YEAR: Type 2 for 1977; 3 for 1978, etc. Even though there are spaces for the year, only one number has to be typed. After entering the code for the current year, press the space bar one time.
7. To set MONTH: Type three digit code for the current month. Type each letter as a capital and press the space bar one time after entering the month code.
8. To set DATE: Type the day of the month. Again only one or two numbers are required even though three places are shown. Press the space bar after entering the current date.
9. To set DAY OF WEEK: Type the three digit code for the day of the week. Enter the code in capital letters and press the space bar after typing the three letters.
10. To set HOURS: The value for the hours is a number from 0 to 23.  
Use the code shown in Figure 3-2 to arrive at the correct value that is to be entered. Again, only one or two numbers are required and the space bar must be pressed after entering the code.
11. To set MINUTES: Enter the minute's value, (from 0 to 59) then press



NOTE: REFER TO TABLE 3-1 FOR IDENTIFICATION OF NUMBERED ITEMS

FIGURE 3-1

FRONT PANEL CONTROLS & INDICATORS



TABLE 3-1  
FUNCTION OF DISPLAY PANEL INDICATORS

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Fig. 3-1 Ref. No.	NAME	DESCRIPTION & FUNCTION
1	Input Indicators	These 32 LED indicators monitor the status of the 32 Digital inputs. An LED is illuminated when it's corresponding input is on.
2	Output Indicators	These 32 LED indicators monitor the status of the 32 digital outputs. An LED is illuminated when it's corresponding output is on.
3	RD Indicator	An LED in the EIA circuit that illuminates when the Sunkeeper is receiving data from the input/output terminal.
4	CTS Indicator (Clear To Send)	An LED in the EIA circuit that illuminate when the interface channel is open and the Sunkeeper can transmit data to the terminal.
5	RTS Indicator (Request To Send)	An LED indicator in the EIA circuits that illuminates when the Sunkeeper requests the communications channel between the unit and the terminal. When the terminal is ready to accept data it issues the CTS signal to the Sunkeeper.
6	TD Indicator (Transmit Data)	An LED indicator in the EIA circuits that illuminates when the Sunkeeper is transmitting data to the terminal.

TABLE 3-1

## FUNCTION OF DISPLAY PANEL INDICATORS

Fig. 3-1 Ref. No.	NAME	DESCRIPTION & FUNCTION
7	Program Scanning Indicator	This LED flickers on at the scanning rate master control program. NOTE: In most instances this rate is so fast that the light does not extinguish.
8	Not Used	For future expansion.
9	Timing Indicator	An LED that turns ON and OFF to indicate proper timing circuit operation.
10	Central Processor	This LED is illuminated when central processor is executing a program.
11	+24V Indicator	An LED that illuminates when the power supply is providing +24VDC.
12	+12V Indicator	An LED that illuminates when the power supply is providing +12VDC.
13	+5V Indicator	An LED that illuminates when the power supply is providing +5VDC.
14	-5V Indicator	An LED that illuminates when the power supply is providing -5VDC.
15	-12V Indicator	An LED that illuminates when the power supply is providing -12VDC.
16	EIA Channel Jack JC	A 25 pin female connector that accepts the communications interface cable from the input/output terminal. (See Table 2-3 for a listing of the signals on each pin.)

TABLE 3-1  
FUNCTION OF DISPLAY PANEL INDICATORS

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Fig. 3-1 Ref. No.	NAME	DESCRIPTION & FUNCTION
17	EIA Channel Jack JD	A 25 pin male connector that extends the communications bus when Sunkeeper's are connected in a daisy-chain configuration (See Table 2-3 for a listing of the signals on each pin.)
18	Digital Outputs Jack JE	A 25 pin female connector that supplies digital outputs 1 through 16. (See Table 2-2 for a listing of the signals on each pin.)
19	Digital Outputs Jack JF	A 25 pin female connector that supplies digital outputs 17 through 32. (See Table 2-2 for a listing of the signals on each pin.)
20	Digital Inputs Jack JA	A 25 pin male connector that accepts inputs 1 through 16. (See Table 2-1 for a listing of the signals on each pin.)
21	Digital Inputs Jack JB	A 25 pin male connector that accepts digital inputs 17 through 32. (See Table 2-1 for a listing of the signals on each pin.)
22	Analog Inputs	A 25 pin male connector that accepts analog inputs 1 through 16. (See Table 2-1 for a listing of the signals on each pin.)

TABLE 3-1  
FUNCTION OF DISPLAY PANEL INDICATORS

Fig. 3-1  
Ref. No.

NAME

DESCRIPTION & FUNCTION

23	Analog Inputs	A 25 pin male connector that accepts analog inputs 17 through 32. (See Table 2-1 for a listing of the signals on each pin.)
24	Power Cord	The AC power cord plugs into a grounded 115VAC, 60 Hz power source.
25	Fuse	A 5 amp fuse that provides overvoltage protection for the Sunkeeper.

TABLE 3-2  
SUNKEEPER ERROR MESSAGE

CODE TYPED	DESCRIPTION OF ERROR
1?	COMMAND NAME NOT FOUND OR NOT YET DONE
2?	FORCED TO TRANSFER TO NONEXISTENT LINE
3?	REMOVED STOP FROM NONEXISTENT LINE
4?	DID NOT HAVE SLASH IN STOP
5?	OUTPUTTED LINE # REFERS TO NONEXISTENT LN
6?	ASKED TO FIND NONEXISTENT LINE #
7?	VALUE OUT OF RANGE IN COMMAND LINE
8?	OPEN OF NEW LINE BUT NO LINE NUMBER
9?	LINE NUMBER NOT VALID
10?	EDIT COMMAND SPECIFIED, BUT NOT IN EDIT
11?	INPUT SETTINGS SPECIFIED IN X1 OR X2 MODE
12?	X1 OR X2 ADDRESS IS FOR DIFFERENT DRUM
13?	AX SPECIFIED WHEN NOT IN X1 OR X2 MODE
14?	UNRECOGNIZABLE RELATIONAL IN ANALOG SPEC
15?	INCORRECT VALUE IN ANALOG SPECIFICATION
16?	TOO MANY ANALOG SPECIFICATIONS FOR BUFFER
17?	ALPHA ARGUMENT NOT FOUND IN TABLE
18?	NUMERIC ARGUMENT > 65K
19?	BAD DELIMETER BETWEEN ARGUMENTS
20?	BAD FIRST DIGIT OF LINE NUMBER
21?	MULTIPLE XE ADDRESSES FOR SAME DRUM
22?	NEW LINE REQUESTED, BUT MEMORY FULL
23?	CAN'T PUNCH WHILE STILL IN EDIT
24?	INVALID DRUM NUMBER

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1 9 7 7  
YEAR

D E C  
MONTH

1 5  
DATE

      
DAY OF WEEK

1 4  
MINUTES  
0-59  
HOURS

2 5  
SECONDS  
0-59

<u>Enter</u>	<u>For</u>	<u>Enter</u>	<u>For</u>	<u>Enter</u>	<u>For</u>
				0	MIDNIGHT
JAN	January	MON	Monday	1	1 AM
FEB	February	TUE	Tuesday	2	2
MAR	March	WED	Wednesday	3	3
APR	April	THR	Thursday	4	4
MAY	May	FRI	Friday	5	5
JUN	June	SAT	Saturday	6	6
JLY	July	SUN	Sunday	7	7
AUG	August			8	8
SEP	September			9	9
OCT	October			10	10
NOV	November			11	11
DEC	December			12	NOON
				13	1 PM
				14	2
				15	3
				16	4
				17	5
				18	6
				19	7
				20	8
				21	9
				22	10
				23	11

FIGURE 3-2  
FORMAT FOR SETTING CALENDAR/CLOCK

ST 1977 SEP 15 THU 11 16 29  
1977 September 15th Thursday 11:16 29 Seconds

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FIGURE 3-3  
TYPICAL CALENDAR/CLOCK PRINTOUT

#### NOTE

If the SECONDS value is not used in control sequences, this can be left blank and the clock set up terminated by a carriage return after setting MINUTES.

13. After entering all values, request a printout of the clock (refer to paragraph 3.6 below) to insure that all codes were entered correctly. If not, start the procedure all over again. Remember that the values printed out will reflect the current time and not necessarily the values you entered. This is because the clock is now running and will continue to keep the correct time. Also, the format printed out will be 7 groups of three values with zeros inserted in the appropriate places. A typical printout is shown in Figure 3-3. This printout is for: 1977, September, 15th day, Thursday, 11:00, 16 minutes, 29 seconds.

### 3.6 CALENDAR/CLOCK PRINTOUT

To produce a printout of the calendar/clock time type: T1 carriage return.

The correct time/date information is displayed as shown in Figure 3-3.

### 3.7 INITIAL CHECK OUT

After entering the calendar/clock data in a newly installed Sunkeeper (See Sec. 3.4) any valves, settings, or factory test program should be erased before entering a new control sequence. To do this perform the following steps:

1. To see if there are any sequences stored in memory. Type the Print Program command: PU (carriage return).

- a) The printout should be: PU CL
- b) If not, type: Z& (carriage return)



- c) Type: PU (Carriage Return)
  - d) Now the printout is: PU CL
  - e) If you entered Z6, the calendar/clock must be reset again.
2. To display the analog inputs (the input cables should still be disconnected) type PA space /(slash) carriage return.
    - a) The printout will list the first 24 analog inputs with a zero next to each, and the last 8 with 255 next to each.
  3. To display the Digital Inputs (cables disconnected) type:  
PI (carriage return).
    - a) The printout will list any digital input that is on. (There should be none on, so nothing will print.)
  4. To display the Digital Outputs (cables disconnected) type:  
PD (carriage return)
    - a) The printout will list any digital output that is on. (There should be none on, so nothing will print.)
  5. To display the status of Internal Memory Bits type: PB (carriage return)
    - a) The printout will list any bits that are on. (There should be none.)

The Sunkeeper is now cleared of any unwanted programming and ready to accept the control sequence. Before writing and entering this sequence, it is recommended that Section 4 be read to acquire a basic understanding of the Sunkeeper's internal architect. This understanding will make it easier to write a unique control sequence and structure it so the maximum power and flexibility of the Sunkeeper can be used to control the system.

It is recommended that all inputs, outputs, analogs and bits be disabled before input and output cables are connected to the Sunkeeper and before any programming is entered in the Sunkeeper.

A. To Disable All Inputs

Enter: D1 SPACE/(slash) CARRIAGE RETURN

B. To Disable All Outputs

Enter: DD SPACE/(Slash) CARRIAGE RETURN

C. To Disable All Analogs

Enter: DA SPACE/(Slash) CARRIAGE RETURN

D. To Disable All Bits

Enter: DB SPACE/(Slash) CARRIAGE RETURN

To verify that all are disabled,

Enter: PX CARRIAGE RETURN

Sunkeeper should print out:

DD 1 - 32

D1 1 - 32

DA 1 - 32

DB 1 -32

Sunkeeper is now ready to accept a program. The program may be initialized and debugged without having any effect on or being effected by any outputs, inputs, analogs or bits. When debugged, enable only those items (drivers, analogs, inputs or bits) used by the program. For more information on procedure used to debug programs, refer to section 6.3 diagnostic commands.

## 4 THEORY OF OPERATION

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### 4.1 GENERAL

Before attempting to write a control sequence for your application or trying to enter a new sequence into a Sunkeeper, it is recommended that you have a basic understanding of the basic operation and structure of the Sunkeeper. By better understanding the unit, you will be able to devise sequences that are not only both easier to write and enter but also you will create sequences that can be easily modified or updated after data logging the system's performance.

### 4.2 BASIC SUNKEEPER FUNCTION

The basic function of a Sunkeeper Control Unit is to turn external equipment on or off at the proper time or in response to specific conditions. The status of the various inputs, the setting of the calendar/clock, and pre-established rules or conditions are used by the Sunkeeper to make these control decisions.

While the logic circuits required to perform these functions are very complex, they are easily represented as a series of mechanical sequence or timing drums that are commonly found in traditional control applications familiar to most maintenance personnel.

Figure 4-1 is a simplified diagram of the control logic of the Sunkeeper. The user's control sequence is represented by the 9 drums in the center of the figure. These drums receive both analog and digital input status signals and the setting of the internal clock. The drums can output to either the 32 memory bits or the 32 output drivers that connect to the external equipment. The complete Sunkeeper operation is controlled by the Master Control Sequence which allows the drums to function as determined by the user's control sequence.

### 4.3 DRUM THEORY

Each of the drums that make up the user's control sequence have locations

or logic lines in which the actual sequence of the specific control program is stored. Drums numbered 1 through 8 have 99 logic lines and drum 9 has ten lines available. The lines are numbered 1000 - 1099 on drum 1, 2000 - 2099 on drum 2, 3000 - 3099 on drum 3, and so forth until drum 9 where the line numbers are 9000 - 9010.

All drums are capable of spinning or rotating as directed by either the Master Control Sequence or the actual user's control sequence on that drum. In this manner, a drum can spin in either direction, skip or jump past unwanted logic lines, or stop at any specific line to process the logic on that line.

Only one line of a drum is processed at any one time and the operation of each drum is independent of the other drums. Some drums may be left idle and not used in the control sequence. Also, of the 99 available logic lines on a drum, not all have to be used before using another drum. The availability of the multiple drums permits the user's control tasks to be divided by unique functions and each assigned to a separate drum. For example: Drum 1 could be assigned all the heating control; Drum 2, the air conditioning; Drum 3, the solar collection; Drum 4, the time clocking, etc.

Because these drums have independent action, there is no direct way for one drum to "talk" to another drum. To compensate for this, a common series of 32 memory bits are able to be accessed by each drum. Every drum can set any one of these memory bits and all drums can read the status of the bits.

#### 4.4 EMERGENCY DRUM

Drum 9 is the Emergency Drum in the User's Control Sequence. This drum has ten logic lines that function the same as the other lines. These 10 lines are used to respond to an emergency condition in the user's equipment. When this drum determines that an emergency condition exists, it removes the control of the other 8 drums from the Master Control Sequence or the sequence being performed at

and causes the drums to spin to logic lines that will rectify the emergency conditions.

An example of an emergency condition might be insufficient water in an electric water heater. An emergency condition on Drum 9 might be defined such that if the "low water" indication comes ON, the drum controlling the heater is reset to a line which turns the heater OFF, and drives a digital output ON to light a lamp or ring an alarm bell. Alternately, the emergency line might turn ON a valve to add water to the heater, and continue doing so until the "low water" indicator went OFF.

#### 4.5 DRUM LOGIC LINES

The function of a drum logic line is to examine the status of inputs, outputs, Memory Bits, or the clock and, after performing the required logic, turn on or off output drivers or set or clear Memory Bits. To perform this function only one line is processed at any one time.

Figure 4-2 shows a typical drum and a single logic line. The "pick-up point" allows the Master Control Sequence to process only one logic line at a time. Each line is divided into the following three sections:

1. Line Action Command
2. Exit Condition #1
3. Exit Condition #2

The Line Action Command is the actual task performed by the line. It commands output drivers to turn on or off, or sets or clears any of the 32 memory bits. Any combination of output states or bit status can be commanded on a single logic line. When a drum stops at a line all line action commands are performed before the logic checks the conditions that allow the drum to turn to another logic line and process that line.

Exit Condition #1 establishes the conditions that must be satisfied before the drum can rotate to the next line in the sequence. Included in the Exit Condition can be any of the possible variables in the system: inputs, outputs, bits or clock. The Exit Condition examines the state of these variables in the following fixed sequence:

1. Output Drivers (On/Off)
2. Inputs (Analog Comparison)  
(Digital On/Off)
3. Memory Bits (On/Off)
4. Analog Exit Specifications (real time)  
(elapsed time)
5. Emergency Conditions

Exit Condition #2 has the same conditions as Exit Condition #1.

Each logic line specifies two sets of exit conditions for transferring control to another line on the same drum. Again these line exit conditions consist of lists of settings or output drivers, digital inputs, limit points for analog inputs, memory bits and time values. The Master Control Sequence checks the exit conditions during each cycle. If one of the two sets of exit conditions is completely satisfied, control is transferred to the associated drum lines on the next cycle. Sets of exit conditions are examined in the order in which they are specified in the control program. If the first set is satisfied, control is passed to its exit line, and the second set is not examined. If neither set of exit conditions is satisfied, the same drum line is processed on the next cycle. If a drum line does not have any exit conditions, the sequence remains on that line until the drum is taken off by an emergency or by operator intervention.

Each set of exit conditions is associated with the number of the line which is to receive control if the conditions are met. This line number must be in the same drum. If the operator specifies an exit line which is not in the same drum,

error messages are generated, and the line is not accepted. It is possible for both sets of exit conditions to transfer control the the same line. One exception is made for line 0. Line 0 is not in any drum, but if an exit condition specifies line 0, the Master Control Sequence interprets the specification to mean that the exit is not taken. If the first exit condition specifies line 0, the controller does not allow the exit, and does not examine the second exit condition.

An exit specification may contain many different conditions involving many different types of information. It is important to note that ALL conditions in an exit specification MUST be satisfied before the exit is performed.

#### 4.5.1 Output Drivers in Exit Conditions

The status of the 32 output drivers can be one of the conditions in an exit condition. A sample specification using output drives is:

FD 6,7  
OD 1,5

This exit condition is satisfied if drivers 1 and 5 are ON and drivers 6 and 7 are OFF.

#### 4.5.2 Digital Inputs In Exit Conditions

Digital inputs have only two states, ON and OFF, and are numbered 1 through 32. The digital input portion of the exit condition is satisfied if all inputs specified to be ON are ON, and all those specified to be OFF are OFF. Digital inputs not mentioned in the exit specification are ignored. A sample digital input exit specification is:

FI 22  
OI 5,8

This exit specification is satisfied if digital inputs 5 and 8 are ON and digital input 22 is OFF.

#### 4.5.3 Analog Inputs In Exit Conditions

Analog temperature inputs are automatically scaled when they are read by the Sunkceper, therefore, trip points are specified in degrees Farenheit. Analog inputs are numbered 1 through 32, and each analog input in the exit condition is associated with a trip point. Analog exit conditions can be satisfied for three reasons: 1) if the analog value exceeds the trip point, 2) if it is less than the trip point, 3) if it is equal to the trip point. Analog inputs which are not mentioned do not participate in the exit condition. A sample analog input specification is:

AX 22>15, 32>2, 12<50, 19=57, 20=5

This condition is satisfied if analog input 22 is greater than 15, input 32 is greater than 2, analog input 12 is less than 50, analog input 19 is equal to 57, and input 20 is equal to 5.

Analog inputs can also be compared with one another. The specification for a trip point based on the difference of two analog inputs contains the names of the two inputs which are to be compared, followed by the trip point. A sample difference specification is:

AX 15-23>180, 27-26>90, 15-14<78, 1-2=3, 1-5=79

This specification is satisfied if analog 15 minus analog 23 is greater than 180, 27 minus 26 is greater than 90, 15 minus 14 is less than 78, 1 minus 2 is equal to 3, and 1 minus 5 is equal to 79. The SCU allows comparisons between analog inputs regardless of type.

#### 4.5.4 Memory Bits In Exit Conditions

The only function of the 32 Memory Bits is to allow communications between drums. To accomplish this task these bits must be used in exit specifications. Because they have no direct external effects, they are only useful in controlling how drum exits are taken. Bits which are not listed are ignored. A sample bit



specification is:

FB 3, 24  
OB 7, 32,

This exit specification indicates that bits 7 and 32 must be ON, and bits 3 and 24 must be OFF.

#### 4.5.5 Real Time In Exit Conditions

The Sunkeeper keeps track of the real time, and maintains special analog variables which reflect the calendar and time of day. These variables are given special names. These names may appear anywhere the Master Control Sequence would expect to find an analog input number. The names and meanings of the calendar variables are listed below:

OUR        Hour of the day. Trip points for OUR are specified as a number from 0 to 23.

DAY        Day of the month. DAY ranges from 1 to 31, and is automatically corrected for the length of the month. DAY changes at midnight, and remains constant until the following midnight.

WKD        Day of the week. WKD can have the values MON, TUE, WED, THU, FRI, SAT and SUN. MON is the smallest value, and SUN is the largest. These values may be used in place of numbers when comparing WKD to a trip point. WKD changes at midnight and remains constant until the following midnight.

MTH        Month. MTH has the values JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, and DEC. JAN has the smallest value and DEC has the largest. These names may be used as trip points for MTH. MTH is corrected for variations in the lengths of months.

#### 4.5.6 Elapsed Time In Exit Conditions

The intervals between events (elapsed time) can be used as a condition in

an exit specification. There are five types of timers available to drums 1 thru 8. All timers are zeroed when control is transferred to a line of that drum. If the timers are part of the exit condition for the line, the condition is satisfied if the timer value exceeds its trip point. (Note that the timers are cleared if an emergency condition for a drum is activated, because the emergency causes a new line to receive control.)

The five timers measure different amounts of time. The timer names and their meanings are as follows:

TID	Time in Days. Counts from 1 to 256 days, and increments at midnight.
TIH	Time in Hours. Counts from 1 to 256 hours, and increments whenever the system minute counter is reset from 59 to 0.
TIM	Time in Minutes. Counts from 1 to 256 minutes. It increments whenever the system second counter is reset from 59 to 0.
TIS	Time in Seconds. Counts from 1 to 256 seconds in seconds.
T.S	Time in Tenths of Seconds. Counts from .1 to 25.6 seconds, in tenths of seconds.

An example of a timer specification in an exit condition is:

AX TID > 4

This condition is satisfied when the timer value is greater than four, which occurs when the drum has been on the same line during five midnights. This timer condition is always satisfied just after midnight. The interval spent on the line could be as short as four days, .1 second, if the line were entered just before midnight on the first day. Because all conditions in an exit specification must be satisfied for the exit to be taken, if more than one timer is contained in a specification, the condition is satisfied when the longest timer times out.

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Timers may also be specified to be less than the trip point, equal to the trip point, or not equal to the trip point. The specification

AX TID < 4

is true so long as fewer than four midnights have occurred. It is unwise to specify an interval in seconds or in tenths of seconds to be precisely equal to some trip point. The timer runs independently of the drum scanning program, and drum scanning takes a variable amount of time depending on how many drums are scanned and how complicated the exit conditions are. Therefore, the tenths of seconds timer may be incremented more than once between drum scans, thereby missing the time specified in the exit condition. Therefore, should not be used with tenths of seconds or seconds.

#### Emergencies in Exit Conditions

Emergency conditions contain a list of conditions to be satisfied, followed by a list of line numbers which are to receive control during the next control cycle. The specifications for an emergency condition follow exactly the same rules as the line exit specifications. Any number of drum lines may be listed for the emergency condition. Emergency conditions are formal line numbers numbered from 9000 to 9010. The only difference is that emergency conditions have only one test, cannot reference timers, cannot set outputs, and may list more than one line which is to receive control.

#### 4.6 SUNKEEPER BLOCK DIAGRAM

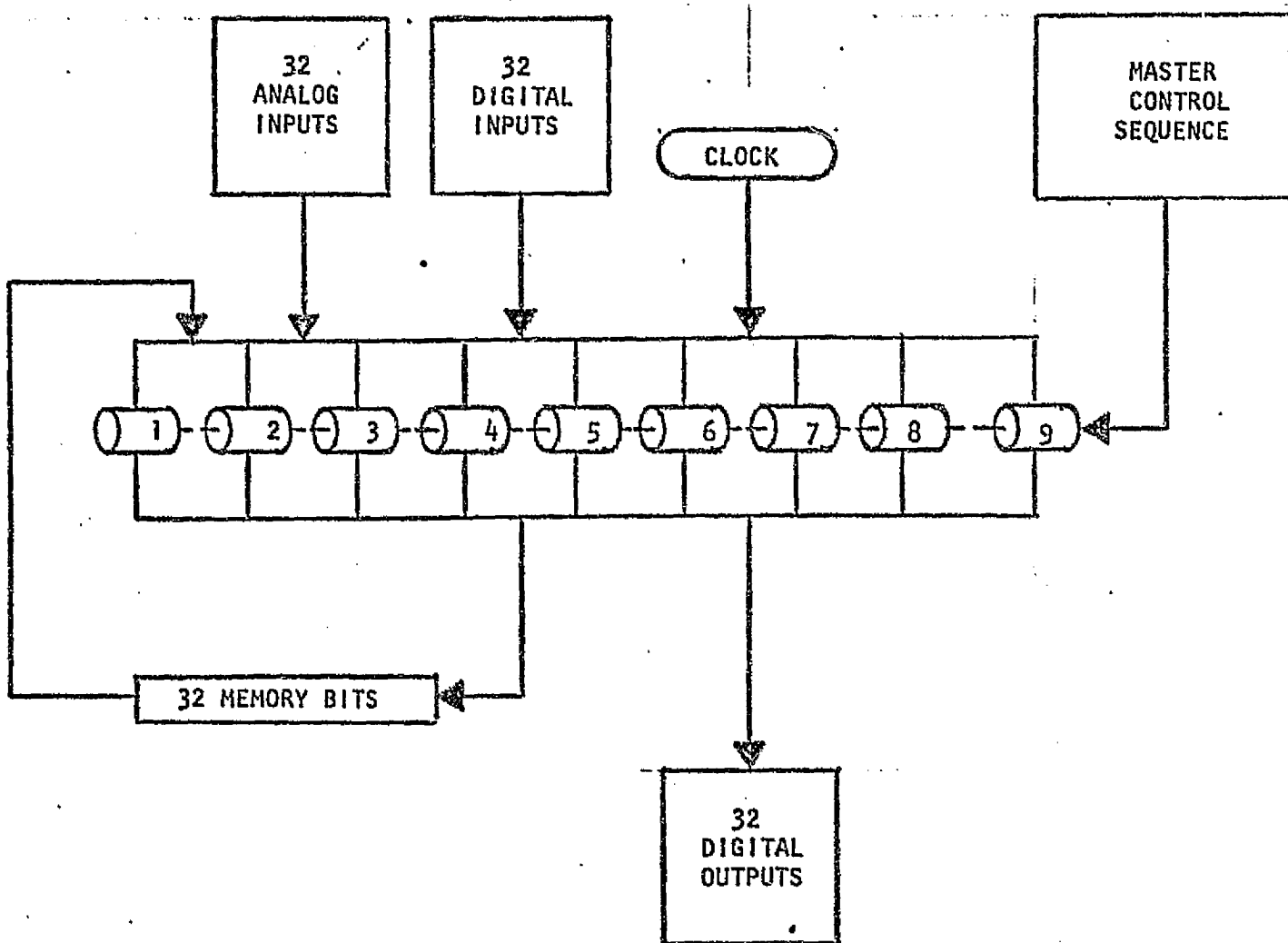
Figure 4-2 contains the simplified block diagram of the Sunkeeper Control Unit. The 32 digital inputs are connected to the unit through connectors JA and JB. These inputs represent the logic state (ON/OFF) of the various switches, relays, or other digital devices in the user's system. All digital input lines are protected from surges on these inputs. The status ...

of the digital input line is displayed on the front panel. An active (ON) input line is indicated by an illuminated light that corresponds to the line number. The 32 analog input lines are connected to the Sunkeeper through connectors JJ and JH. These inputs are also fused for overvoltage conditions but their status is not displayed on the front panel. All inputs are applied to the control logic block. This block contains the following three main parts of the internal logic: Master Control Sequence - This block of logic provides the overall control for the operation of the drums and the Sunkeeper unit. The sequence is stored in non-erasable PROMS which allows the user complete flexibility in writing, operating, or editing his sequence with the confidence that the master sequence can not be altered. This block communicates with the user through the computer interface at connector JC.

User's Control Sequence - This is the block of logic where the drums were used to explain the operation. The actual user's sequence is stored here. This block has inputs from the digital and analog inputs, the clock, the internal Memory Bits and the Master Control Sequence. Outputs from this block are the 32 digital drives at connectors JE and JF. This block also sends or receives data through the computer interface to other Sunkeepers connected to JD.

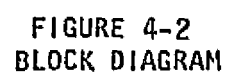
Memory - This block contains the memory locations required for storing the data associated with normal Sunkeeper operation. The memory data is available to both the Master Control Sequence and the User's Sequence.

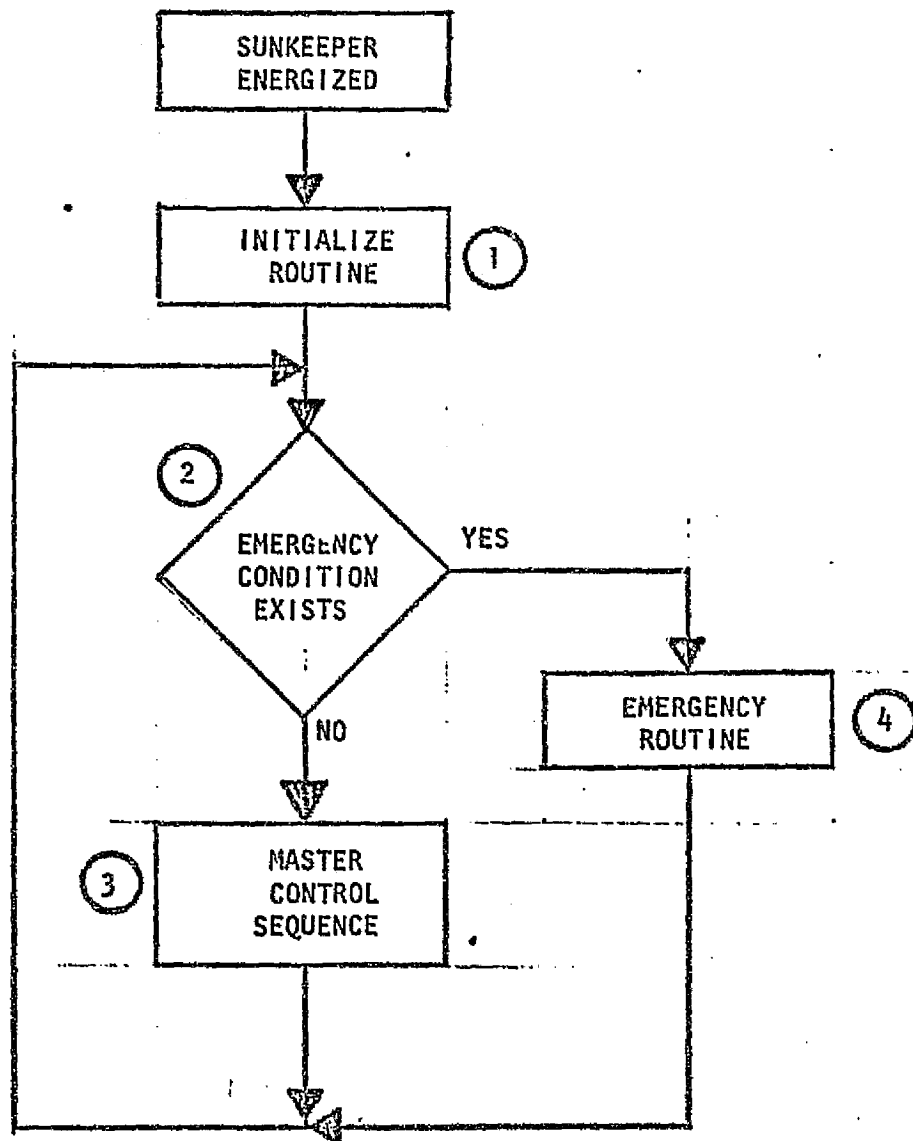
The status of the 32 digital outputs is displayed in the front panel lights. An output that is ON has the light associated with it illuminated. The status of all outputs is fed back to the Control Logic to be used in exit conditions, data logging, or enable/disable functions.



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FIGURE 4-1  
FUNCTIONAL DIAGRAM OF SUNKEEPER





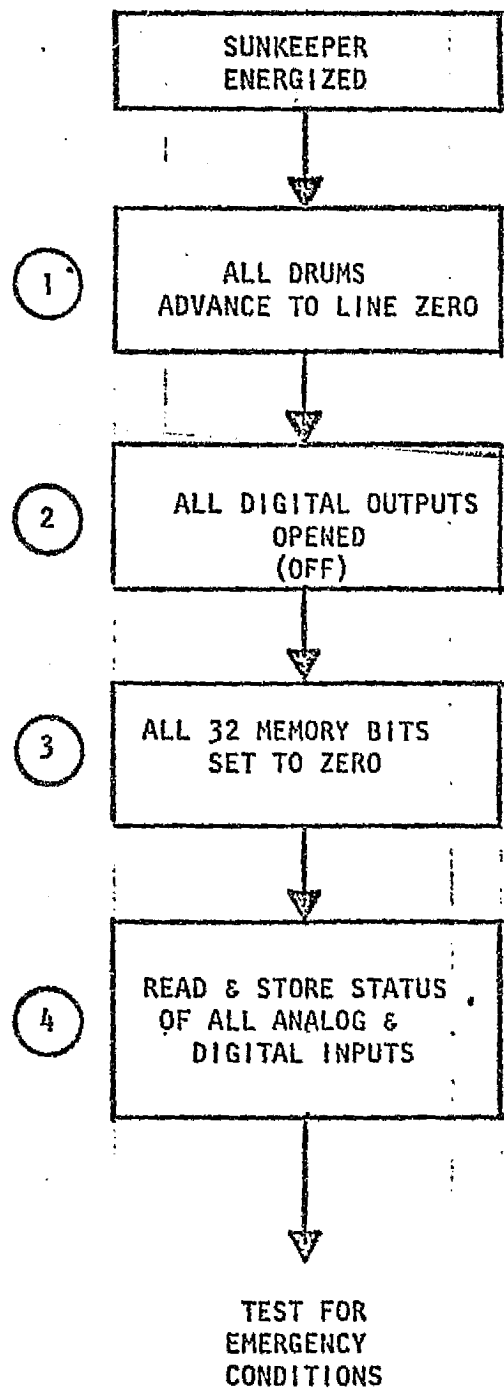


FIGURE 4-4  
INITIALIZE ROUTINE



TEST FOR  
EMERGENCY CONDITIONS

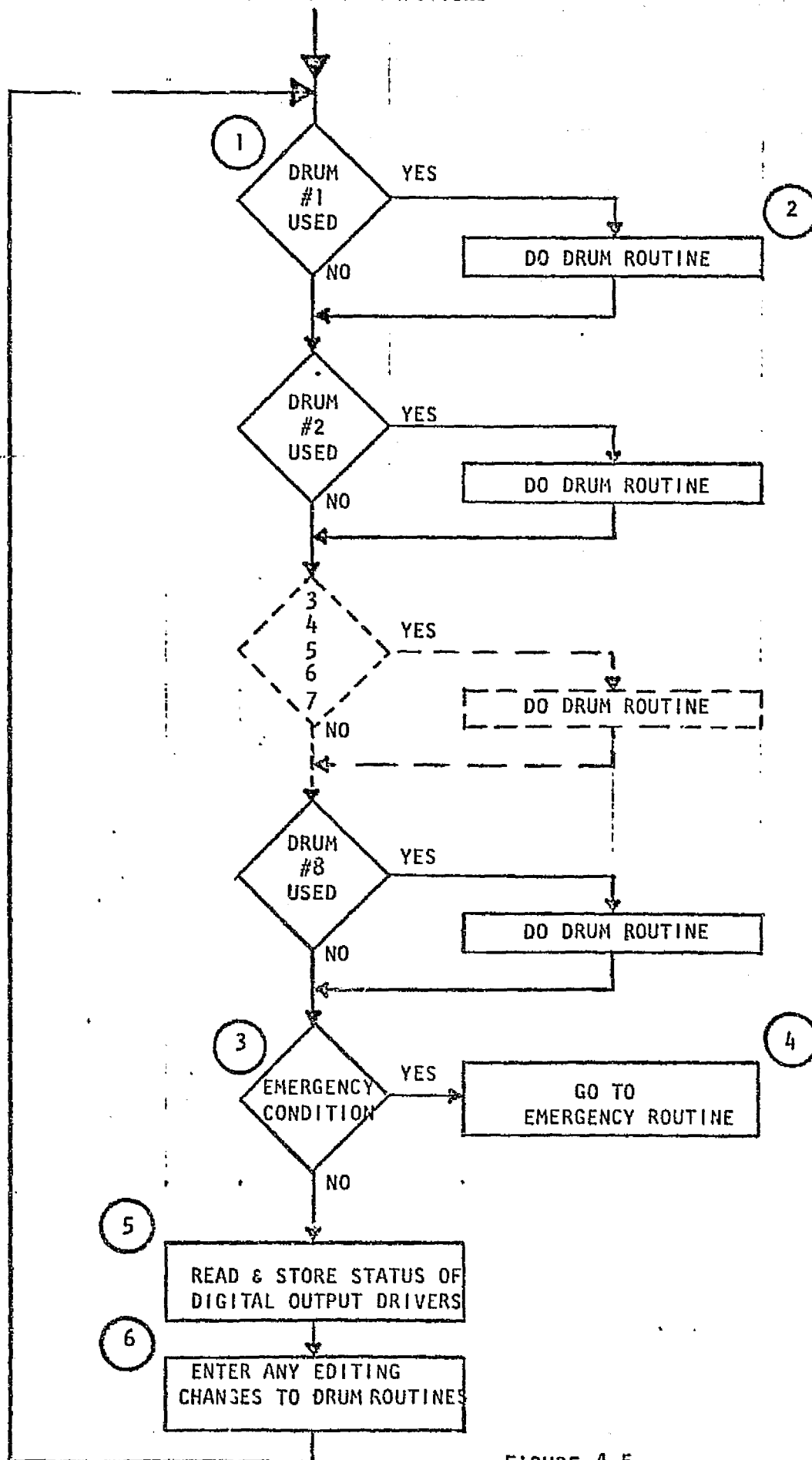


FIGURE 4-5  
MASTER CONTROL ROUTINE

ENTER FROM DRUM ROUTINE  
PERFORMED ON PRECEDING DRUM

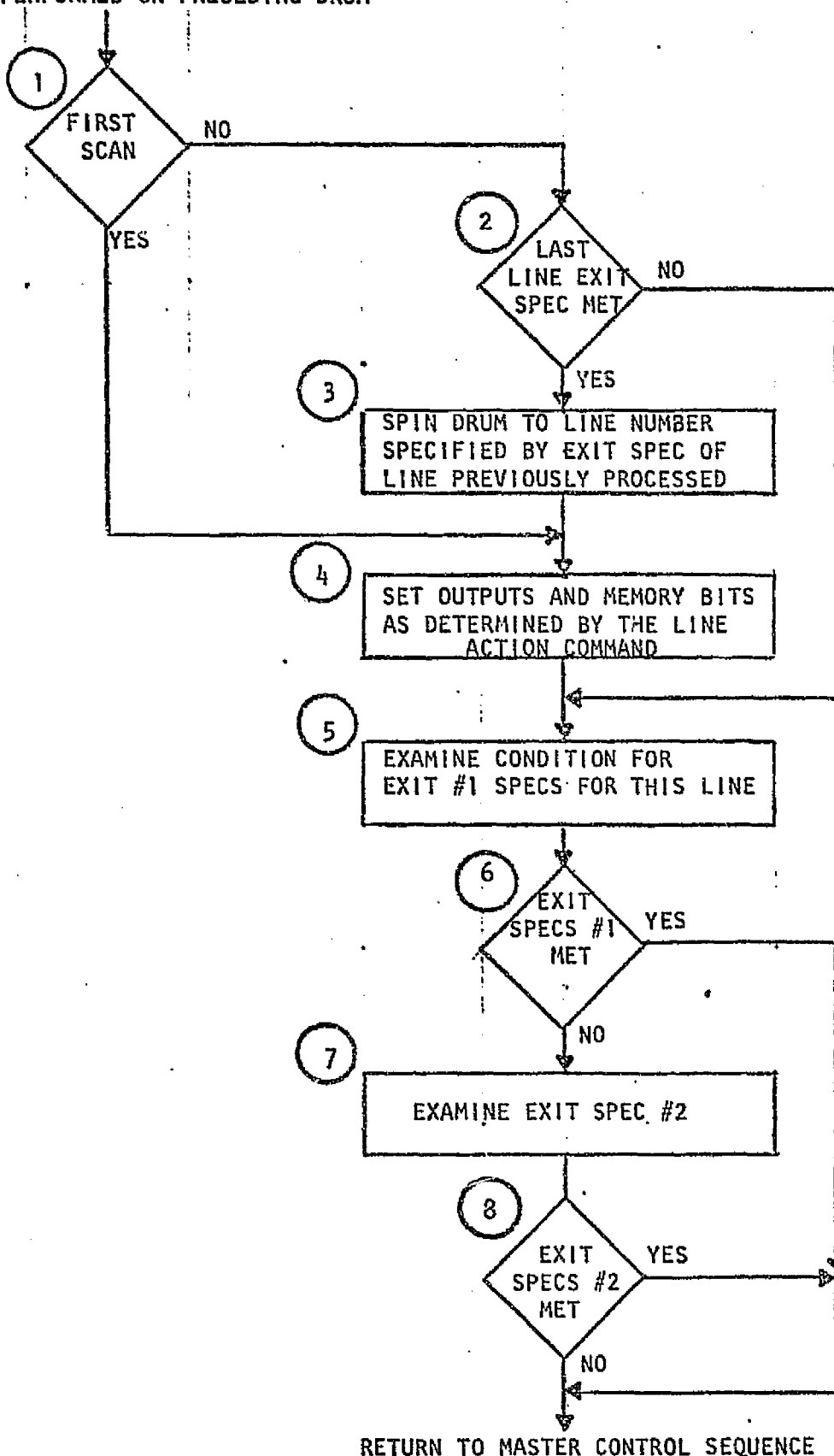


FIGURE 4-6  
TYPICAL DRUM ROUTINE  
Page 4-16

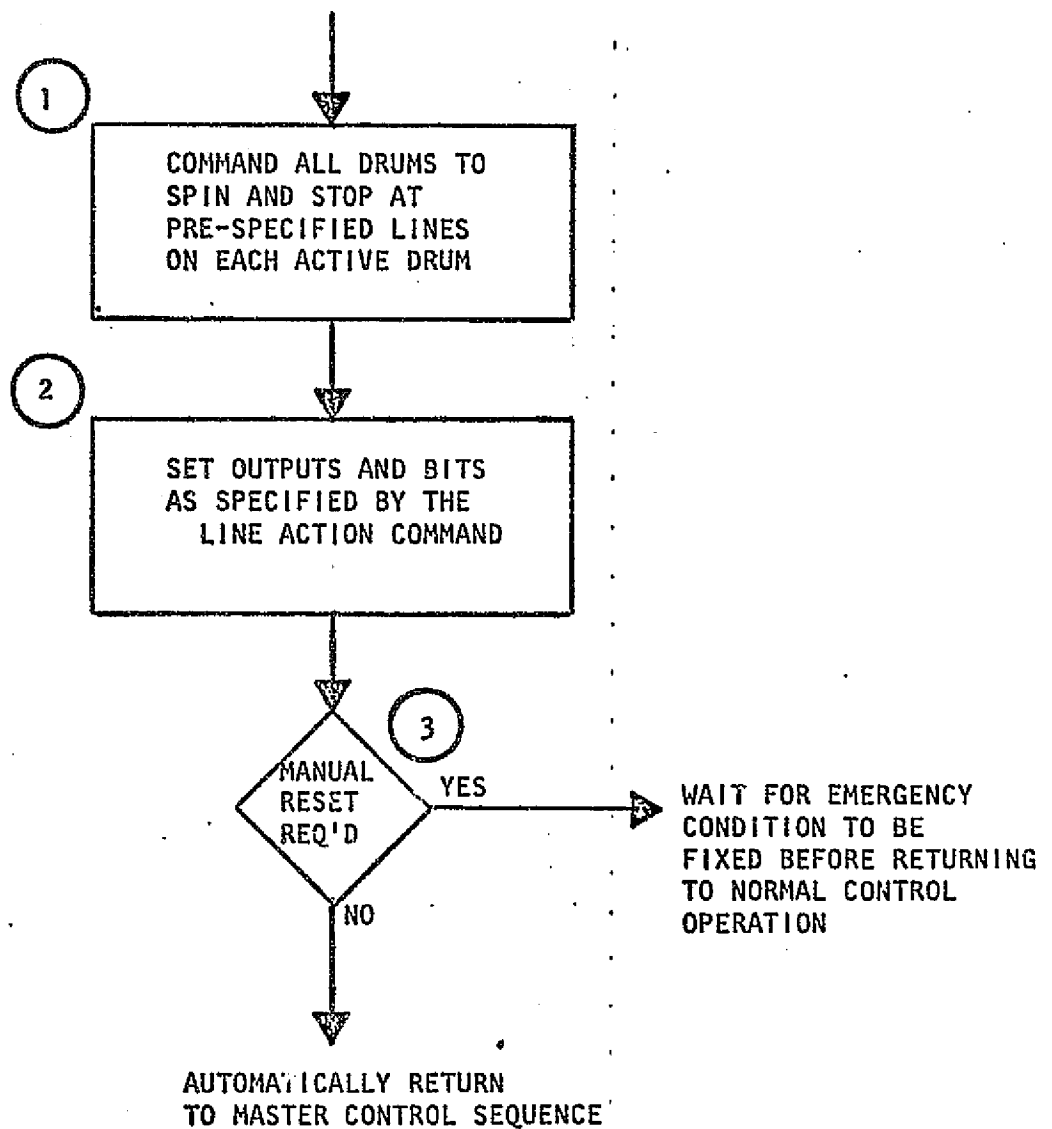


FIGURE 4-7  
EMERGENCY ROUTINE

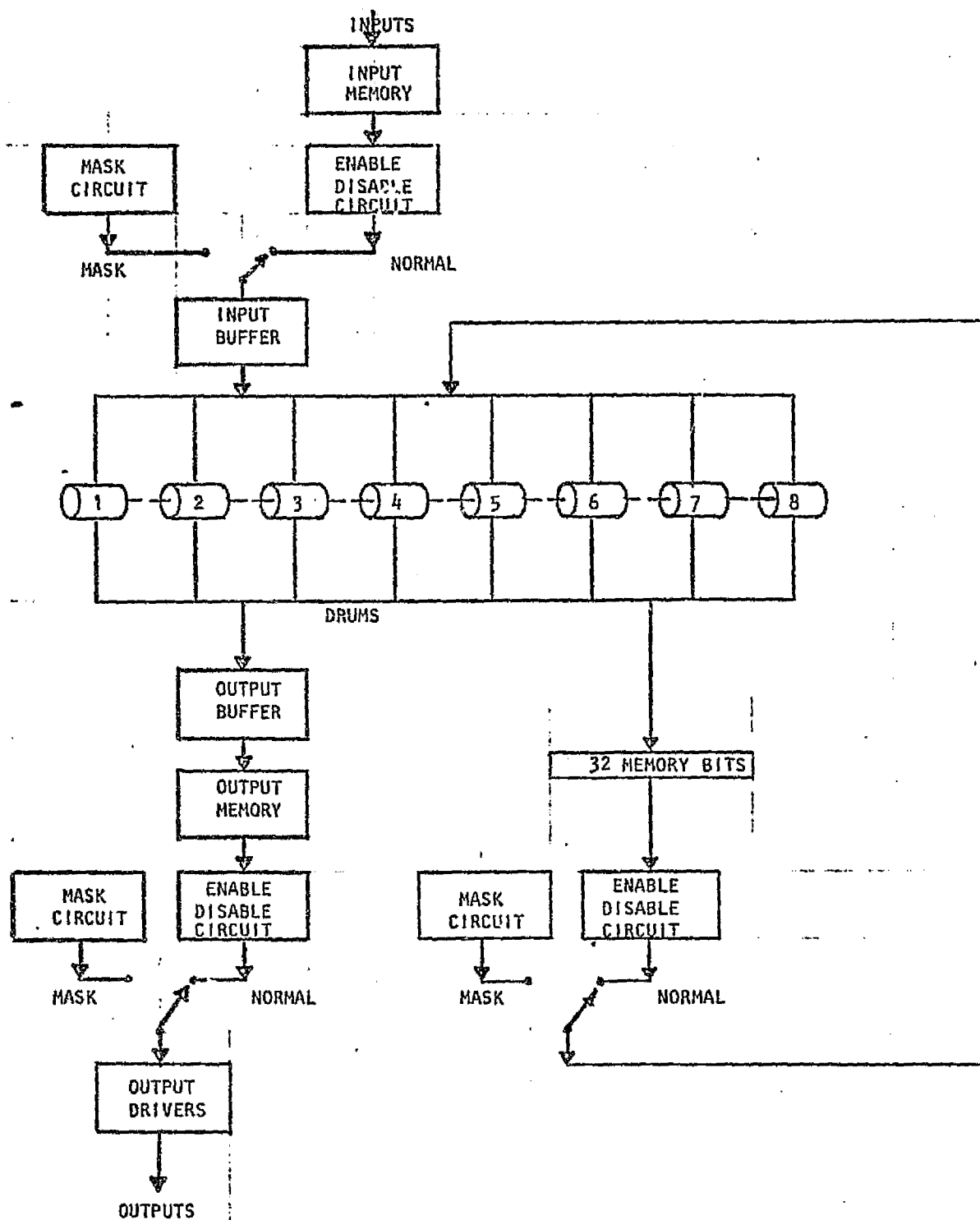


FIGURE 4-8  
ENABLE/DISABLE FUNCTIONS OF  
SUNKEEPER

## 4.7 OPERATIONAL SEQUENCES

The flow diagrams in Figures 4-3 through 4-7 depict the sequences performed by the logic in both the Master Control Sequence and the User's Sequence.

### 4.7.1 Basic Operating Sequence

Figure 4-3 contains the flow of the overall Sunkeeper operation. The circled numbers next to the event blocks in Figure 4-3 reference the following paragraphs:

- (1) The first thing the Sunkeeper does after being energized is perform the Start Routine. This routine is only performed at initial start-up and is not exercised again during normal operation. A detailed flow of this routine is shown in Figure 4-4 and described in paragraph 4.7.2.
- (2) After starting, a test for an emergency condition is made. If no emergency exists, the Master Control Sequence takes command and starts normal operation.
- (3) The Master Control Sequence provide the framework for the drum operations which contain the actual User's Control Sequence. A detailed flow of this routine is shown in Figure 4-5 and described in paragraph 4.7.3.
- (4) A detected emergency condition causes the Master Control Sequence to perform the Emergency Routine. A detailed flow of the emergency routine is shown in Figure 4.7 and described in paragraph 4.7.5

### 4.7.2 Start Routine

The Initialize Routine flow sequence is shown in Figure 4-4. The circled numbers next to the event blocks in this figure reference the following paragraphs:

- (1) All nine drums spin and stop, positioning the pick up point at logic line zero of each drum.
- (2) All 32 digital output drivers are turned OFF.
- (3) All 32 Memory Bits are cleared to zero.

- (4) The status of the 32 digital and analog inputs is read and these values are stored in the RAM for use by the drums.

The Initialize Routine exits to the test for emergency conditions. Depending on the results of the test, the Sunkeeper either performs the Master Control Sequence Routine or the Emergency Routine.

#### 4.7.3 Master Control Sequence Routine

Figure 4.5 shows the flow sequence for this routine. The circled numbers next to the event blocks reference the following paragraphs:

- (1) The Master Control Sequence starts by testing to see if the user assigned part of his control sequence to Drum #1. If no, the sequence repeats the test until it locates a drum that is used.
- (2) Whenever a drum is used, the Master Control Sequence branches to the drum routine for this drum then, when finished, returns to test to see if the next drum is used. A detailed flow of the Drum Routine is shown in Figure 4-6 and described in paragraph 4.7.4.
- (3,4) Another test is made for an emergency condition. If none exists the sequence continues. If an emergency is detected, the sequence branches to the Emergency Routine.
- (5) After servicing all drums, the status of all output lines is read and stored in memory locations.
- (6) Any editing changes made in the logic lines of the drum since the last scan are now entered.

This flow represents one scan of the Master Control Sequence. Typically a scan takes about one second to complete, but the number of drums used and the logic required to satisfy the exit specification of the lines can change the scan time. The Sunkeeper continues to perform the drum scanning routine under the control of the Master Control Sequence until an emergency condition occurs or the unit is turned off.

#### 4.7.4 Drum Routine

The typical routine for a drum is shown in Figure 4-6. This routine is performed once for each of the drums during a Master Control Sequence scan. The circled numbers next to the event blocks in Figure 4-6 reference the following paragraphs:

- (1) Upon entering a drum routine, the Master Control Sequence tests to see if this is the first scan after start-up. If yes the drum performs the Line Action Command. If NO, the sequences advance to Step 2.
- (2) Here a test is made to see if the Exit Specification for the line previously processed on this drum was met. If met, the drum sequence advances to step 3. If not met, the sequence advances to step 5.
- (3) If an exit spec was met on the last scan, the drum spins and stops at the line number determined by that spec.
- (4) The Line Action of this new logic line is performed.
- (5) The First Exit Spec is examined.
- (6) If ALL conditions of Exit Spec #1 are met the sequence is over for this drum and on the NEXT scan of this drum the drum will spin to the line specified in this First Exit Spec. If all conditions are not met the sequence advances to Step 7.
- (7) The Second Exit Spec is examined.
- (8) If ALL conditions are met, the sequence is over and on the next scan the drum will stop at the line specified in this exit specification. If this spec is not met, the routine also terminates, but on the next scan, the drum does not spin and Steps 5 through 8 of this drum routine are repeated until one of the exit specifications is met.

After completing a routine on one drum the Master Control Sequence repeats the routine on the next drum.

#### 4.7.5 Emergency Routine

The flow diagram for the Emergency Routine is shown in Figure 4-7. The circled numbers next to the event blocks in this figure reference the following paragraphs:

- (1) When the Master Control Sequence detects an emergency condition, this routine overrides the sequence in progress and commands all drums to spin and stop at pre-specified line locations that can respond to emergencies.
- (2) After stopping, each drum (in order) performs its Line Action (sets outputs or bits) as in a normal drum routine.
- (3) Depending on the type of emergency, the Master Control Sequence may allow the emergency condition to be terminated through the exit specifications on the new lines or it may wait for human intervention before normal control is returned to the Sunkeeper.

#### 4.8 ENABLE/DISABLE FUNCTIONAL OPERATION

After User's Control Sequence is loaded into the drum section of the control logic it is possible for the user to logically disconnect the Sunkeeper from the control system in order to modify certain sections of the sequence without effecting the control system. When operating in this disconnected mode, the drums ignore the real settings of the inputs, outputs and Memory Bits, and the status of the output drive does not change even though the Sunkeeper remains physically connected to the control system.

Figure 4-8 shows the familiar functional diagram of the drums that make up the User's Control Sequence. The major differences between this diagram and the one previously discussed are the Enable/Disable circuits and the mask switches located in the input, output, and memory bit paths.



In normal operation, the Enable/Disable circuits are enabled for all lines and the Mask switch is in the Normal position. This allows the drum sequences to use the actual input and Memory Bit values in solving the logic lines.

In certain instances during setup or debugging procedures, the user may want to disable an input, output, or Memory Bit to remove this from his logic equations. The Enable/Disable circuits permit any individual line or bit to be blocked so that the drum sequence does not have access to the value of that line. After a line is disabled, the user can assign a value to this line by requesting a mask value from the mask circuits. These new values can now be used by the drums.

#### NOTE

After the performance of a sequence that is using disabled lines or masked values, these user specified values must be removed before the Sunkeeper can control the system in a normal manner.

### 4.9 DATA LOGGING

In data logging applications 16 user specified inputs or outputs are sampled at a fixed rate. The user determines what lines are to be sampled and what the sampling interval is to be used. Sampling intervals can be as short as one minute to as long as 256 minutes.

The Sunkeeper reads each selected parameter once a minute (this is the fixed rate). If a user selected a sampling interval of 30 minutes, at the end of this interval the Sunkeeper would have about 30 values for each parameter (the fixed rate reads each parameter once a minute). This value is stored in memory. The Sunkeeper starts accumulating new values for the parameters and at the end of the sampling interval (30 minutes) again throws out the highs and lows then averages and places these new values in memory next to the first values.

NOTE

For digital inputs or outputs the percentage of ON time is the value that is stored in memory.

The Sunkeeper repeats the sampling sequence 32 times before the memory log is full after 16 hours. The log contains 32 averaging intervals for the 16 parameters (each reading made up 30 averaged readings). If at the end of 32 samplings, the log is not cleared (read out) the next values (from the 33 sampling) cause the values from the oldest sampling (first) are lost. This is because there are only 32 locations available for storing the results of 16 sampling sequences.

## SECTION 5

HOW TO WRITE A CONTROL SEQUENCE

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### 5.1 GENERAL

This section contains the basic guide lines that are recommended for first-time users attempting to write their own control sequences. While these procedures are recommended they are in no way considered the only way to approach a control problem and should provide the basis of many acceptable methods.

### 5.2 ESTABLISHING INITIAL PARAMETERS

At the time you have received your Sunkeeper most of the basic control parameters of your system should have been identified. These include the number of output drivers needed to control your external equipment and the number and function of the various input monitoring signals.

The first recommended step in this guideline is to write (in English) a simple control sequence for your particular system. Start with the first event you want performed and then continue through the normal operation of your system. The easiest place to start is to list each function that is to be controlled by the output drivers of the Sunkeeper. Number each major control step, so you can make reference to them from other steps.

After the first pass through the sequence, go back and examine each control step to see if all conditions required for each step have been included. Be sure to consider all possible inputs from sensors or monitors in the system, in addition to the inputs from the internal calendar/clock.

Don't be discouraged if you find the sequence being restructured as you add conditions and combine or increase the steps. Also, don't forget to include provisions for out-of-tolerance or emergency conditions as required in each step.

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After the second pass, or when you are reasonably sure that the basic sequence has been established, you can assign output line and drum numbers to the various control steps that control the operation of the equipment in your system. Start with the first step of your sequence and give the first output used the name Driver #1 and assign to an action line on Drum #1 (See Fig. 4-2)

NOTE

Because the Sunkeeper has the capacity for 99 lines it is easy to consider each output driver as having its own unique line. Thus all operations effecting the status (ON/OFF) of a driver come from a single drum. Two action lines minimum are required for any driver or group of drivers. One line for "ON" the other for "OFF".

Continue assigning driver and drum numbers until all steps in the sequence have been examined. Groups of drivers having similar control operating conditions should all be assigned to a single drum.

NOTE

Even though the Sunkeeper has the capacity to handle up to 32 drivers, you do not have to find uses for any line you don't require for your sequence.

### 5.3 IDENTIFYING REQUIRED INPUTS

Go back through the sequence again and at each step establish whether a time value is required as an input condition to perform or complete the step. There are two basic types of time values that can be used:

#### Real Time or Elapsed Time

Real time can be the month, day, date, hour, or minute that an event is to take place (e.g.; Tuesday, November 1, 1977 at 2:45 AM).

Elapsed time is measured intervals that occur between control events. The elapsed time uses the outputs of the internal clock to increment to

the desired count. These increments can be in tenths of seconds, seconds, minutes, or hours. Any whole number from 1 to 256 can be preset as the desired count.

#### 5.4 USE OF INTERNAL MEMORY BITS

As you established your control sequence there are specific times when certain output drivers can not be on when other drivers are also on. A typical instance could occur if both the heaters and air conditioners handling the same area are on at the same time or, in another instance, if a tank was intentionally being drained and the driver that controlled the fill valve allowed liquid to flow into the tank. Because each driver is assigned to a separate drum and the drums can not directly communicate with each other, the 32 internal memory bits are used to transmit specific status from one drum to all other drums. These bits can be accessed (read, set, or cleared) by all the drums and can be used to help prevent unwanted interaction between driver functions. For example, in the above case of the heater and air conditioner being on in the same room, as the heater is energized by its driver it could also set memory bit #5. Now a condition that would allow the air conditioner to energize could state that Bit #5 must be cleared before the air conditioner could start.

With this knowledge of the operation of the memory bits, go back through your sequence again and locate any possible conflicting conditions between drivers. Use Form #1 (see next page for this simple form) as a guide and assign each conflicting condition a bit number. Using Form #1 will insure that you do not use the same bit number for more than one condition. Also remember that if you set a bit to acknowledge a certain condition, generally it should be cleared before the conflicting condition is allowed to occur.

PROGRAM:

DATE:

<u>BIT #</u>	<u>FUNCTION</u>
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
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32	
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34	
35	
36	
37	
38	
39	
40	

FORM #1      MEMORY BIT    ASSIGNMENTS

## 5.5 WRITING THE CONTROL SEQUENCE

Now you should be ready to write your control sequence in a manner that will allow you to enter it into the logic lines in the drums without too much rewriting or restructuring if you sequence.

A few general items to remember as you proceed through this critical part:

- 1) Each driver or group of similar drivers should be assigned to a specific drum which can have up to 99 logic lines. The total number of logic lines in ALL DRUMS can not exceed 120.
- 2) The 99 available lines on Drum #1 are designated 1000 to 1099, on drum #3 line numbers are 3000 to 3099 and so forth for all drums.
- 3) On the first pass through your sequence use as many logic lines as you think you need. You can always go back and combine lines later. The most important consideration should be that all events and conditions are covered rather than trying to minimize the number of lines used in the sequence.

A form similar to Form #2 is recommended when you are writing your final control sequence. This form guides you through all possibilities for each logic line. Using Form #2 requires you to answer the following six questions for each logic line:

- 1) Line Number: This is the reference number of the logic line. It consists of the drum number and the line number. On Drum #1 the line numbers are prefixed with 10 then the line numbers from 00 to 99. For example: 1037 is line 37 of Drum #1.
- 2) Action Command: This is the command that actually controls the status (ON/OFF) of the driver assigned to this drum. The Action Command can also contain commands that change the status of any of the 32 memory bits. Acceptable commands are:

On Driver	OD X
Off Driver	FD X
On Bits	OB X
Off Bits	FB X

Note that if the logic line specified is line 00 of any drum, the driver associated with that drum should be set to the condition (either on or off) that configures the equipment in the proper state for initial start up.

- 3) Exit to Line #: The line number entered here is the line on this drum to which the drum spins and stops at if the first exit condition is met. Any valid line on this drum is acceptable.
- 4) Exit Condition #1: (If this specification is met): This is where the conditions for leaving this logic line are listed. These conditions are usually preceded by either an EXIT ALL (XL) or an EXIT ANY (XA) command and are listed in the following order:

- Status of Bits
- Status of Drivers
- Status of Digital Inputs
- Analog Inputs Compared
- Time (Real and Elapsed) Compared

- 5) Exit to Line #: The second line number is entered here. This line is accessed if the exit condition for the first line was not met AND Exit Condition #2 are met.
- 6) Exit Condition #2 (if this specification is met): The conditions for exiting to the second line are listed here. They have the same format as listed in the first exit conditions above.



If you fill out a copy of Form #2 for every logic line of each drum, you will write your complete control sequence in the easiest and fastest possible method.

Use the commands discussed in Section 6 to enter your sequence into the Sunkeeper. After the complete sequence is loaded and the Sunkeeper is controlling your system, you can utilize the data logging function to monitor and analyze the performance of your sequence and then you can use the Editing Commands to alter your sequence for optimum performance.

FORM #2

1. Line Number \_\_\_\_\_

2. Action Command \_\_\_\_\_

3. Exit to Line # \_\_\_\_\_

IF

This Specification is met

4. Exit Condition #1 \_\_\_\_\_

OR

5. Exit to Line # \_\_\_\_\_

IF

This specification is met

6. Exit Condition #2 \_\_\_\_\_

### SAMPLE PROGRAM

Figure 5-1 shows a simple sample program using only one drum. The reader should test his or her understanding of the SUNKEEPER by deducing the functions of this program and then entering it into a SUNKEEPER and verifying the understanding.

PU  
 DP 1000  
     FD 1,5,8  
     X1 1001  
         DI 5  
     X2 1003  
         DI 9  
 DP 1001  
     X1 1002  
         DI 8  
         AX TIS>30  
     X2 1000  
         FI 5  
 DP 1002  
     DD 1,5,8  
     X1 1000  
         FI 8  
     X2 0000  
 DP 1003  
     FD 1  
     X1 1000  
         AX TIS>5  
     X2 0000  
 DP 2000  
     DD 3-4,6  
     X1 2001  
         AX TIM>15  
     X2 0000  
 DP 2001  
     FD 3-4,6  
     X1 2000  
         AX TIM>15  
     X2 0000  
 DP 3000  
     FB 32  
     X1 3001  
         AX OUR>14  
     X2 0000  
 DP 3001  
     DB 32  
     X1 0000  
     X2 0000  
 CL  
 R

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Figure 5-1

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SECTION 6  
SUNKEEPER PROGRAMMING COMMANDS

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## 6.1 GENERAL

This section describes the control commands that are used with the Sunkeeper Control Unit. These commands are divided into the following three groups:

1. Programming Commands
2. Diagnostic Commands
3. Print Commands

Descriptions of the commands associated with each group are given in the following paragraphs. Commands are listed alphabetically by the abbreviation for the commands. A typical example of each command is given to further explain the function and use of the command in normal Sunkeeper operations.

## 6.2 PROGRAMMING COMMANDS

Programming commands are used to set up the Sunkeeper for initial operation, enter the Action and Exit specifications of a control sequence into drum lines, or edit an existing sequence.

The Programming Commands are divided into the following four major groups:

1. Initialize Commands
2. Action Commands
3. Exit Commands
4. Editing Commands

### 6.2.1 Initialize Commands

The following eight commands are listed alphabetically with the full command name printed in capital letters and the actual command that is entered into the Sunkeeper is enclosed in parenthesis. If a command has multiple arguments, an X is included in the parenthesis with the abbreviation.

#### ATTENTION (&N)

The Attention command is used as the first command sent to the Sunkeeper prior to entering any other commands.

User Enters: &N

Sunkeeper Action: Unit is now ready to accept all other valid commands. Next command sent is usually the four digit address code of the desired unit.

#### DISCONNECT (&G)

The Disconnect command is used to terminate communications with the Sunkeeper.

User Enters: &G

Sunkeeper Action: Unit is disconnected from the I/O terminal and does not respond to further commands.

#### RELOAD (RL X)

The Reload command has two functions:

1) User Enters: RL/

Sunkeeper Action: The program tape is loaded from the tape reader into RAM. The paper tape must be mounted in the reader prior to issuing this command.

Clear Drum (ZMX)

User Enters: ZM3

Sunkeeper Action: All lines on Drum 3 are erased. Any valid drum number can be used.

RUN (RU)

The Run command is used to start the Master Control Sequence.

User Enters: RU

Sunkeeper Action: All drums spin and stop at line zero and commence normal line processing.

SET TIME (ST XXX XXX XXX XXX XXX XXX)

The Set Time command configures the calendar/clock for the current time.

The time values are entered in the following order: year, month, date, day of week, hour, minute. The complete procedure for setting the clock is described in paragraph 3.5 and an example is given below:

User Enters: ST 2 JUL 15 FRI 14 18

Sunkeeper Action: Clock is set for 1977, July, 15, Friday, 2:18 PM and will continue to run from this time.

CLEAR HISTORY FILE (ZH)

The Clear History File command erases the data logging values.

User Enters: ZH

Sunkeeper Action: All values stored in data logging section of memory are erased.

REINITIALIZE ENTIRE SYSTEM (Z&)

The Reinitialize Entire System command erases all user entered commands and settings.

User Enters: Z8

Sunkeeper Action: All memory locations are erased, clock is not set,  
only Master Control Sequence is not effected.

ZAP DRUM (ZM X)

The Zap Drum command clears the all line action and exit conditions for the drum line specified.

User Enters: ZM 8

Sunkeeper Action: All user entered conditions on drum 8 are cleared.  
This drum is now blank.

### 6.2.2 Action Commands

The following four commands can be entered in the Action portion of the logic line. These commands either turn on or off the drivers that connect to the external equipment or set or clear the internal memory bits.

TURN OFF BIT (FB X)

This command causes the bits specified to reset to zero (off). Valid terms for X are 1 through 32. Memory bit designations can be separated by commas. Unspecified bits are not effected.

User Enters: FB 1,6,21,29

Sunkeeper Action: Internal Memory Bits 1, 6, 21 and 29 are reset to zero when the line containing this Action Command is processed.

TURN OFF DRIVER (FD X)

This command causes the output driver lines specified to de-energize (turn-off). Valid terms for X are 1 through 32. Unspecified lines are not effected.



User Enters: FD 6,8,10

Sunkeeper Action: Output driver lines 6, 8, and 10 are turned off when the line containing this Action Command is processed.

#### TURN ON BITS (OB X)

This command sets memory bits. Valid terms for X are 1 through 32.

User Enters: OB 2,4

Sunkeeper Action: Memory bits 2 and 4 are set (turned on) when the line containing the Action Command is processed.

#### TURN ON DRIVERS (OD X)

This command turns on (energizes) the specified output driver lines.

Valid terms for X are 1 through 32.

User Enters: OD 7-13

Sunkeeper Action: Output lines 7 through 13 are energized when the line containing this Action Command is processed.

### 6.2.3 Exit Commands (Refer to sample program section 6.5)

Each logic line has provisions for two Exit Conditions. These conditions are established using combinations of the various analog or digital Exit Commands listed below:

#### EXIT CONDITION ONE (X1) \_\_\_\_\_

This command specifies that all other commands or conditions in this exit specification must be met before the line exits to a new line. This command is considered as an "AND" function.

User Enters: X1 \_\_\_\_\_; 0B1, 4 FD7-10

Sunkeeper Action: The exit condition containing this command is satisfied only when Memory Bits 1 and 4 are on and output drivers 7 through 10 are de-energized.

#### EXIT CONDITION TWO (X2)

This command specifies that all of the commands or specifications in this Exit Specification shall be met for the line to exit to another line. This command is considered as an "OR" function, with respect to Exit Condition one

User Enters: XZ \_\_\_\_\_: 0B6,3

Sunkeeper Action: The exit condition for this line is satisfied if either bit 6 or bit 3 is ON.

#### DIGITAL EXIT VALUES

The following six digital (ON/OFF) conditions can be included in Exit Specifications for a logic line:

Digital Input Lines On (OI X)

Digital Input Lines Off (FI X)

Internal Memory Bits On (OB X)

Internal Memory Bits Off (FB X)

Output Driver Lines On (OD X)

Output Driver Lines Off (FD X)

#### ANALOG EXIT (AX Text)

This command specifies the analog exit conditions that must be met to satisfy the line. The text part of the command can consist of up to 4 analog values. These numbers can be values from the analog input lines, clock values, or set points. These numbers must be separated by one of the

following designations: Page 6-6

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- , (Comma)
- < (Less Than)
- > (Greater Than)
- = (Equal To)
- (Minus)

The comma (,) is used to separate groups of commands in the condition. The greater than (>), less than (<) and equal to (=) designations specify the relationship between the value of the analog variable on the left and the set point on the right. The logic in the Master Control performs the indicated comparison and, if it is correct, this part of the exit condition is satisfied. The minus (-) designation specifies that the value of the analog variable on the right is subtracted from the analog variable on the left. All negative results are indicated as a zero value. (Minus sign is dash on keyboard of terminal unit).

The following Calendar/Clock values can be used in the Analog Exit Command.

#### REAL TIME

Month of Year (MT)	JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC
Day of Month (DAY)	1 through 31
Day of Week (WKD)	MON, TUE, WED, THR, FRI, SAT, SUN
Hour (OUR)	0 through 23 with 0 being midnight

#### ELAPSED TIME

Time in tenths of seconds (T.S)	.1 to 25.6
Time in seconds (TIS)	1 to 256
Time in minutes (TIM)	1 to 256
Time in hours (TIH)	1 to 256
Time in days (TID)	1 to 256

User Enters: AX 1>22, 2-5<100, WKD=SUN,

Sunkeeper Action: This specification is true only on Sundays

when the temperature on analog input line one is greater than 22 degrees and the difference between the analog values on input lines 2 and 5 is less than 100 degrees.

Note: the temperature scale is nonlinear, therefore, the value of a difference depends on the temperatures when the calculation is made.

#### 6.2.4 Editing Commands

These commands are used to access the drum lines and specify where (Action or Exit portion of the line) the commands are applied.

##### OPEN (OP X)

This command opens either a logic line or the data logging line. When X is any valid logic line number this line is opened. When D is entered in place of a line number, the data logging line is opened. As long as a line is open, the Sunkeeper types E instead of R whenever it is ready for the next command. Changes to the line do not take effect until the line is CLOSED. If OP is issued while another line is open, the other line is automatically CLOSED first. When a line is first opened, the Action Command (specifying the bit and driver settings) may be modified using the On and Off commands.

User Enters: OP 5002

Sunkeeper Action: Line 2 on Drum 5 is opened and ready to accept new or additional commands to the logic line.

## CLOSE (CL X)

This command terminates the editing mode for the current logic line. Changes made to the line do not take effect until the line is closed with this command. Until the line is closed, the original text of the line can be recovered by exiting from the editing mode using the XX command, then using the Open Command (OP) to open the line again. The Close command can be issued while the Sunkeeper is performing normal operations. Therefore, if new lines are added to the program while the Sunkeeper is running, the new line should be added before any exiting lines are changed to refer to these new lines. This is because a new line can not effect the control sequence because no existing line can reference it. The Close command checks all lines to insure that none of them referenced lines that do not exist, and does not close the present line if there is a reference error.

User Enters: CL 6015

Sunkeeper Action: Line 15 of drum 6 is removed from the editing mode.

## FIRST EXIT LINE (X1 X)

This command sets line X as the first exit for the line being edited. Further changes to the line affect the first exit condition. X1 may only be used during editing. Line 0 may be specified, in which case neither the first nor the second exit will ever be examined. If no line number is specified at all, the exit line number is not changed, and future editing changes are directed to the first exit specification.

User Enters: X1 5003

Sunkeeper Action: If the first exit condition, for this line is met,  
drum 5 spins to line 3.

## SECOND EXIT LINE (X2 X)

This command sets a line as the second exit for the line being edited. Further changes to the line affect the second exit condition. X2 may only be issued during editing. Line 0 may be specified, in which case the second exit will never be examined. If no line number is specified at all, the exit line number is not changed, and future editing changes are directed to the second exit specification.

User Enters: X2 8017

Sunkeeper Action: If the first exit specification was not met and the second was, drum 8 spins to line 17.

## EMERGENCY EXIT SPECIFICATION (XE X)

This command takes a list of up to 300 line numbers specifying the lines to which the drums are rotated if the emergency condition is satisfied. XE may be issued only when editing an emergency line or a data logging line. When editing a data line, only the first number may be specified, and it establishes the number of minutes between data averaging.

1) User Enters: XE 1005, 2015, 3028, 7052

Sunkeeper Action: Drum 1 spins to line 5  
Drum 2 spins to line 15  
Drum 3 spins to line 28  
Drum 7 spins to line 52  
All other drums do not rotate

2) User Enters: XE 15

Sunkeeper Action: The line this command was entered in will be data logged every 15 minutes.

## TERMINATE EDIT WITHOUT CLOSING (XX)

This command leaves the editing mode without issuing a CLOSE command.

Any changes to the line are discarded. This is useful when inappropriate changes have been made to a line and it is desirable to return to the initial state.

User Enters: XX

Sunkeeper Action: Original commands on line being edited are retained and any new editing commands are disregarded.

### 6.3 DIAGNOSTIC COMMANDS

Diagnostic commands are used to modify the operation of an existing control sequence or to force a sequence to perform with a given set of inputs. Generally, when operating in the diagnostic mode the drum lines are electrically disconnected from the external equipment and the logic receives inputs from these user generated commands.

#### 6.3.1 Alter Analog Input Command

In certain instances, the value on an analog input line is replaced with a known value regardless of the actual value of the input.

ALTER ANALOG (AA X Y)

This command permits a value (Y) to be inserted on analog input value X. Any valid input value number can be specified for X and any value from 1 to 256 can be used in Y. In order for this value to persist in spite of efforts by the thermistors to change it, the analog input must be DISABLED. AA does not disable the input. The specified value is kept until the input is ENABLED or until it is changed by another AA command.

User Enters: AA 2007 126

Sunkeeper Action: The current value of line 7 on drum 2 is replaced with 126

### 6.3.2 Clear Commands

These commands clear or turn off the specified input, bits, or drivers.

#### CLEAR BIT (CB X)

This command resets the specified memory bits. The bits reset immediately but may be altered by another line unless the drum containing that line is disabled.

User Enters: CB 1, 7, 19

Sunkeeper Action: Memory bits 1, 7 and 19 are reset to zero.

#### CLEAR & DISABLE DRIVER (CH X)

This command both turns off and disables the output drivers specified by X. This command does not affect the condition of the drivers as seen by the drum lines. This command is generally used to set hardware conditions that are not to be changed.

User Enters: CH 7, 8, 25

Sunkeeper Action: Drivers 7, 8, 25 are disabled and turned off.

#### CLEAR INPUT (CI X)

This command causes the specified digital inputs to be seen as OFF by the drums. If these inputs are not disabled, this command will only persist for one scan then the input will assume its correct status.

User Enters: CI 4-8

Sunkeeper Action: Digital input lines 4 through 8 are off.



### 6.3.3 Disable Commands

Disable commands freeze the values of the specified inputs, outputs or bits at the current status. Neither the external equipment nor the program can alter the values of disabled items. Only after being enabled can these values change. The appropriate set and clear commands for disabled items only affect the way the drums process the data but does not have any effect on the control system.

#### DISABLE ANALOG (DA X)

This command freezes the value of the specified analog input(s). Until the input is Enabled, the value can be changed only by an Alter Analog command.

User Enters: DA 5, 9, 24

Sunkeeper Action: Analog input lines 5, 9 and 24 are disabled.

#### DISABLE BIT (DB X)

This command prevents the specified memory bit(s) from changing except in response to a SET BIT or CLEAR BIT command.

User Enters: DB 18, 27, 30

Sunkeeper Action: Memory bits 18, 27 and 30 are frozen at their current state.

#### DISABLE DRIVER (DD X)

This command disconnects the output drivers from the drum program and leaves these outputs in their current state. SET and CLEAR do not affect the hardware of DISABLED drivers, but the Sunkeeper regards the SET or CLEAR as having taken place for purposes of testing the output drivers.

User Enters: DD 5,8

Sunkeeper Action: Output drivers 5 and 8 are disabled.

## DISABLE INPUT (DI X)

This command leaves digital inputs in the state they are in at the time of the DISABLE. SET and CLEAR commands may be used to change the state of a DISABLED input.

User Enters: DI 1-5, 8

Sunkeeper Action: Digital inputs 1 through 5 and line 8 are disabled.

## DISABLE DRUM (DM X)

This command prevents the specified drum from having any effect on drivers or memory bits. The output and memory settings generated by the disabled drum are saved and can be examined using the print commands. Under these circumstances, driver and memory settings generated by any drums are saved for examination using the print commands.

User Enters: DM 1,6

Sunkeeper Action: Drums 1 and 6 are disabled,

### 6.3.4 Enable Commands

Enable commands remove the effect of Disable commands and allow the status of the previously frozen inputs, bits, or drivers to change and reflect the current state of the equipment. Whenever an input is Enabled, the hardware sensor determines if current values and, on the next scan, this value is used by the drums. When an output driver is Enabled, the drive status is not changed until a drum line changes it.

## ENABLE ANALOG (EA X)

This command enables the specified analog input lines.

User Enters: EA 5

Sunkeeper Action: Analog input five is enabled

#### ENABLE BITS (EB X)

This command enables the specified memory bits.

User Enters: EB 7,9,30

Sunkeeper Action: Memory bits 7, 9, 30 are enabled

#### ENABLE DRIVERS (ED X)

This command enables the specified output driver lines.

User Enters: ED 4-6, 18

Sunkeeper Action: Output drivers 4, 5, 6 and 18 are enabled

#### ENABLE INPUTS (EI X)

This command enables the specified digital input lines.

User Enters: EI 7,11

Sunkeeper Action: Digital input lines 7 and 11 are enabled.

#### ENABLE ALL (EL)

This command removes all disables. It does not require that the items be specified.

User Enters: EL

Sunkeeper Action: All disables are removed.

#### ENABLE DRUM (EM X)

This command enables the specified drums

User Enters: EM 5,8

Sunkeeper Action: Drums 5 and 8 are enabled

### 6.3.5 Set Commands

Set commands force an input, bit, or output to the on condition.

#### SET MEMORY BIT (SB X)

This command sets the memory bits specified. The change takes place immediately. This state may be changed by a drum, depending on the program and whether or not the drum is Enabled.

#### SET & DISABLE OUTPUT DRIVER (SH X)

This command disables and sets (turns on) the specified output drivers. The command does not affect the status of the drivers as seen by the drums.

User Enters: SH 1,

Sunkeeper Action: Output driver lines 1 and 8 are disabled and appear turned on to the drums.

#### SET INPUT (SI X)

This command sets (turns on) the specified digital inputs. This set value may be changed on the next scan if the input is not disabled.

User Enters: SI 8, 25

Sunkeeper Action: Digital input lines 8 and 25 are turned on (set).

### 6.3.6 Drum Commands

Drum commands effect the operation of the drums when in the diagnostic mode.

#### ADVANCE DRUM LINE (AV X Y)

This command forces the line specified in X to exit to the line number initiated in the first exit specification, if the value of Y is 1 or to the

line in the second exit specification if Y is 2. This action does not require that either exit condition be met.

User Enters: AV 2013 2

Sunkeeper Action: Drum 2 leaves line 13 and spins and stops at the line number specified in the second exit condition of line 13.

#### REMOVE DRUM LINE STOP (NS X)

This command removes the stop condition from the specified line. If "/" is entered for the line, all stop conditions are removed. Although this command indicates that a drum is no longer inhibited from leaving the current line, it does not necessarily follow that the drum will leave the line. In order for the drum to leave the line, the exit conditions must be satisfied. A stop condition does not prevent the operator from leaving the line by using the Advance Drum Line (AV) or Rotate (RM) commands.

User Enters: NS 1015, 6008

Sunkeeper Action: The stop condition on line 15 of drum 1 and line 8 of drum 6 are removed.

#### ROTATE THE DRUM (RM X)

This command rotates the specified drum to the specified line. The action command for this new line is not processed until the next control cycle. All timers for the drum are cleared. The drum may, of course, be moved from the specified line during the next cycle, depending on its exit specifications and emergency conditions.

User Enters: RM 5028

Sunkeeper Action: Drum 5 spins and stops at line 28 but does not perform the Action command until the next control scan.

## RESET OF LINE ZERO (RS)

This command causes all drums to be reset to line 0. This command may be issued whether the Sunkeeper is running or not.

User Enters: RS

Sunkeeper Action: All drums spin and stop at line zero.

## STEP A DRUM LINE (SL X)

This command causes the Sunkeeper to process the Action Command for line X. Inputs are not scanned, and the exit conditions for that line are not examined. This may or may not affect the driver hardware, depending on whether or not the drum or the drivers are ENABLED. The effect is as if the Sunkeeper had transferred to that line for one scan and then resumed processing the line it was on at the time the command was issued.

User Enters: SL 5051

Sunkeeper Action: The Action command for line 51 of drum 5 is executed and remains on that line for one scan then goes back to the line it was processing when the SL command was received.

## STOP (SP X)

This command stops the drum specified in X. This drum is not examined at all during the control cycles. A stopped drum may be restarted by rotating it to the appropriate line using the RM command. An argument of "/" stops all drums and thereby halts the control program. This turns off the RUN light. All outputs are left as they were at the end of the cycle. SP / is an extremely drastic command and is not recommended for normal use.

## 6.4 PRINT COMMANDS

The Print Commands allow the user to select the values and status of the Sunkeeper during various operations.

### PRINT ANALOG (PA X)

This command prints the hardware value and the drum value of one analog input. If a numerical argument is supplied, only the specified input is printed. If "/" is specified, all analog inputs are printed in a list. If the value of the analog input has been frozen by a DISABLE command, the first value is the value to which the input has been frozen, and the second is the hardware value. If the analog input is not disabled, the two values are the same.

### PRINT THE BIT MEMORY (PB)

This command prints just the memory bits that are ON (set) it presents these bits as seen by the drums, which may or may not be the same as the actual bit states depending on the status of the Disable command. PB / lists the actual bit states.

### PRINT DRIVERS (PD)

This command lists the output drivers which are ON. This information duplicates the display lights for drivers which are not disabled. If a driver is disabled, the state printed is the state the driver hardware would assume if the driver were not disabled. PD / prints the state of the hardware.

#### PRINT HISTORY FILE (PH)

This command prints the history data logged in the system. The data logger can handle up to 16 variables. Up to 32 averages are recorded in the history storage. The history printout gives the beginning hour and minute at which each sample was taken, the number of minutes between each average, and the values of the 16 variables. The time is also given.

#### PRINT DIGITAL INPUTS (PI)

This command lists the digital input lines which are ON. This information duplicates the indicator lights on the front panel for inputs which are not Disabled. The value printed for Disabled inputs is the value to which they were last SET, regardless of the state of the hardware. If the hardware state is desired, a "/" argument to the print command should be given.

#### PRINT DRUM LINE (PL X)

This command prints the text of drum line X. If the line is being edited at the time of the PL, the printed line is the state of the line before it was edited. If the PL command is not given a line number, the state of the line as it would be if a CLOSE were to be given is printed instead. This allows the operator to verify the edited line before closing and inserting the changes in the control sequence.

#### PRINT DRUM (PM X)

This command prints all the lines in drum X. This is a handy means of reviewing the program for a specific drum. "/" indicates that all drums are to be printed.



#### PRINT CURRENT DRUM POSITION (PP X)

This command prints the logic line of the specified drum that is being processed at the time the PP command is received.

#### PUNCH THE PROGRAM (PU)

This command causes the Sunkeeper to punch the users program from its memory. This generates a program listing (if a teletype punch is used).

#### PRINT DISABLED (PX)

This command lists all inputs, bits, and output drivers that are disabled.

#### PRINT TIME (TI)

This command causes the Sunkeeper to print the current value of its clock. The print is in the form YY MM DD WKD HH MM SS. The clock is read at the time the print starts, so the printed value is off by the amount of time taken to do the printing.

### 6.5 SAMPLE PROGRAM

Refer to Figure 6-1 for a sample program that illustrates format and use of exit conditions.

Refer to Figure 6-2 for a sample print out of the history file and method for identifying data.

EN _____ (ID.CODE)	OP 1009
TI	OD 2
TI 006 JUL 001 TUE 017 035 002	FD 1
P	X1 1010
PU	AX TIS>5
OP 1000	X2 0000
FD 1-5,7	OP 1010
X1 1001	FD 1-2
OI 3.5	X1 1006
X2 1006	AX TIS>4
OI 4-5	X2 1000
OP 1001	FI 5
OD 4.7	OP 1011
X1 1003	OD 5
AX 25>90,TIS 4	X1 1006
X2 1002	AX TIS>4
AX TIS>5	X2 1000
OP 1002	FI 5
X1 1004	
AX 25<80,TIS>4	
X2 1005	
AX TIS>5	
OP 1003	
OD 1	
FD 2	
X1 1005	
AX TIS>4	
X2 0000	
OP 1004	
OD 2	
FD 1	
X1 1005	
AX TIS>4	
X2 0000	
OP 1005	
FD 1-2	
X1 1001	
AX TIS>4	
X2 1000	
FI 5	
OP 1006	
OD 4	
X1 1008	
AX 6 215,TIS>4	
X2 1007	
AX TIS>5	
OP 1007	
XL 1009	
AX 6 205,TIS>4	
X2 1011	
AX TIS>5	

Figure 6-1

# SAMPLE HISTORY FILE

EN

TI 006 JUL 001 TUE 017 039 015

P

OP D

E

PL

OP 10000

OD 4

AX 25-26-27-28-29-2-3-4-5-6-7-8-9=0

XE 0015

E (Note: 1st two columns on left are time. All others to the right  
CL are data in order given above)

P

PH

009	035	000	065	064	054	255	255	076	078	078	078	115	113	101	076	000	000
009	050	000	065	064	057	255	255	078	080	080	080	115	113	101	076	000	000
010	005	000	065	064	061	255	255	081	082	082	082	115	113	101	076	000	000
010	020	000	065	064	062	255	255	084	085	085	085	115	113	101	076	000	000
010	035	000	065	064	062	255	255	087	088	088	089	115	113	101	076	000	000
010	050	000	064	064	062	255	255	091	092	092	092	115	113	101	076	000	000
011	005	000	065	064	063	255	255	094	095	095	096	115	113	101	076	000	000
011	020	000	065	064	063	255	255	097	098	099	099	115	113	101	076	000	000
011	035	000	064	064	062	255	255	100	102	102	102	115	112	101	076	000	000
011	050	000	065	064	062	255	255	105	106	106	106	115	112	101	076	000	000
012	005	000	064	064	062	255	255	108	109	109	109	115	113	100	076	000	000
012	020	000	065	064	063	255	255	111	112	112	113	115	113	100	076	000	000
012	035	000	065	064	063	255	255	115	116	116	116	115	113	100	076	000	000
012	050	000	065	110	066	255	255	111	113	113	113	115	113	100	103	000	000
013	005	000	065	116	067	255	255	111	113	113	113	128	126	095	112	000	000
013	020	000	066	116	066	255	255	107	108	108	108	135	134	096	108	000	000
013	035	000	067	116	066	255	255	107	108	108	109	136	135	113	110	000	000
013	050	000	068	116	067	255	255	111	112	112	112	137	136	115	113	000	000
014	005	000	068	114	067	255	255	113	114	114	114	138	137	115	115	000	000
014	020	000	068	115	068	255	255	114	115	115	115	137	136	115	115	000	000
014	035	000	068	107	068	255	255	114	115	115	115	137	136	115	115	000	000
014	050	000	068	104	066	255	255	114	115	115	115	137	136	115	116	000	000
015	005	000	068	104	065	255	255	114	115	115	115	137	136	115	116	000	000
015	020	000	067	104	065	255	255	114	115	115	115	137	136	115	116	000	000
015	035	000	068	104	065	255	255	114	115	115	115	138	137	115	116	000	000
015	050	000	068	105	063	255	255	114	115	115	115	138	138	115	116	000	000
016	005	000	067	104	063	255	255	114	115	115	115	138	137	115	116	000	000
016	020	000	067	105	063	255	255	114	115	115	115	135	134	115	116	000	000
016	035	000	067	105	063	255	255	114	115	115	115	132	131	115	116	000	000
016	050	000	067	085	061	255	255	114	115	115	116	127	126	115	117	000	000
017	005	000	065	063	059	255	255	116	118	118	118	127	126	114	119	000	000
017	020	000	064	063	059	255	255	114	115	115	115	127	126	111	117	000	000

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SECTION 7  
MAINTENANCE & TROUBLESHOOTING

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7.1 MAINTENANCE PHILOSOPHY

The Sunkeeper Control Unit requires no extraordinary maintenance procedures. Typically the only care requires is such that would normally be given to similar electronic equipment. The Sunkeeper's rugged construction and use of all solid state components should provide many trouble-free hours of control operation.

7.2 TROUBLESHOOTING

The first step in trying to isolate troubles in a system that is controlled by a Sunkeeper is to find out whether the malfunction is in the controlled equipment (sensors, relays, valves, etc.) or in the Sunkeeper.

Disconnect the input control wiring to the Sunkeeper at input connectors JA, JB, JJ and JH. Request that the analog and digital input valve be printed. All should read zero.

Insert an Analog Input Tester into connector JH and read the inputs on analog input pins 1 through 16. These should compare with the values supplied with the tester. Then insert the tester in connector JJ and read the values for analog inputs 17 through 32.

If any of the readings are incorrect, the out-of-tolerance channel is not considered to be reliable and should not be used.

NOTE

If there are other or spare input channels available, the load wiring normally connected to the defective channel should be attached to a good spare input channel.

To check the digital inputs, insert a Digital Input Tester in connectors JA and JB then read the values on lines 1 - 16 and 17 - 32 respectively.

Output drivers can be checked by monitoring the lines at the point where they connect to the external equipment and observing the front panel status lights that illuminate to indicate a driver that is ON.

There are no repair procedures for a defective Sunkeeper Unit. The unit should be shipped back to the factory for repair.

### 7.3 USE OF PHONE IN CENTER

Sunkeeper installations having a telephone modem on their Input/Output terminal can take advantage of a unique Sunkeeper diagnostic feature. By calling the Sunkeeper Service Center and attaching the telephone handset to the mode, the local Sunkeeper can be operated under the control of a special diagnostic program run at the service center. This feature can determine the operational status of the Sunkeeper and also help isolate faults.

### 7.4 HYDRONIC SYSTEM MAINTENANCE

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#### 7.4.1 Circuit Setter Valves

These valves require no maintenance. If one should malfunction or leak, remove it and replace with a new valve. The procedure for using these valves is explained in Appendix A-2.

#### 7.4.2 Modumate Zone Control Valves

These valves require no maintenance. These valves are operated by a heat motor. In the event of a failure, turn "OFF" power in the control panel,

remove wiring, remove motor and replace. See Appendix A-5 for valve cuts.

#### 7.4.3 Griswold Constant Flow Controls

These items require no maintenance. In the event of failure, replace.

For ordering information refer to Appendix A-4.

#### 7.4.4 Pumps

The pumps require routine maintenance. Refer to Appendix A-3.

#### 7.4.5 Isolation & Draining

Removal of any item in the hydronic system piping requires that the I.P.E.C.H. package be isolated from the external piping systems. Valves and drain plugs are provided for this purpose.

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C-2

# APPENDIX A

## COMMAND LIST

### PROGRAMMING (EDIT)

AX ANALOG EXIT SPECIFICATION  
 CL CLOSE LINE BEING EDITED  
 FB BITS WHICH ARE OFF/TURN OFF BIT  
 FD DRIVERS WHICH ARE OFF/TURN OFF DRIVER  
 FI INPUTS WHICH ARE OFF  
 OB BITS WHICH ARE ON/SET BIT  
 OD DRIVERS WHICH ARE ON/TURN ON DRIVER  
 OI INPUTS WHICH ARE ON  
 OP OPEN A DRUM LINE FOR EDIT  
 PU PUNCH THE PROGRAM  
 RL RELOAD THE DRUM LINES  
 RU RUN THE PROGRAM  
 ST SET TIME  
 X1 FIRST EXIT SPECIFICATION  
 X2 SECOND EXIT SPECIFICATION  
 XE EMERGENCY EXIT SPECIFICATION  
 XX GET OUT OF EDIT WITHOUT CLOSING  
 ZH CLEAR HISTORY FILE  
 Zs REINITIALIZE ENTIRE SYSTEM  
 ZM ZAP DRUM

### PRINT

PA PRINT ANALOG  
 PB PRINT THE BIT MEMORY  
 PD PRINT DRIVERS  
 PH PRINT HISTORY FILE  
 PI PRINT DIGITAL INPUTS  
 PL PRINT DRUM LINE  
 PM PRINT DRUM  
 PP PRINT CURRENT DRUM POSITION  
 PU PUNCH THE PROGRAM  
 PX PRINT DISABLED  
 TI PRINT TIME

### DIAGNOSTIC

AA ALTER ANALOG VALUE  
 AV ADVANCE DRUM LINE  
 CB CLEAR BIT  
 CH CLEAR & DISABLE OUTPUT DRIVER HARDWARE  
 C: CLEAR INPUT  
 DA DISABLE ANALOG  
 DB DISABLE BIT  
 DD DISABLE DRIVER  
 DI DISABLE INPUT  
 DM DISABLE DRUM  
 EA ENABLE ANALOG  
 EB ENABLE BIT  
 ED ENABLE DRIVER  
 EI ENABLE INPUT  
 EL ENABLE ALL  
 EM ENABLE DRUM  
 NS REMOVE DRUM LINE STOP  
 RM ROTATE THE DRUM  
 RS RESET TO LINE ZERO  
 SB SET MEMORY BIT  
 SH SET AND DISABLE OUTPUT DRIVER HARDWARE  
 SI SET DIGITAL INPUTS  
 SL STEP A DRUM LINE  
 SP STOP  
 TI PRINT TIME

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## TIME

### REAL TIME

MTH Month of year (JAN,FEB,MAR,APR,MAY,JUN,  
 JUL,AUG,SEP,OCT,NOV,DEC)  
 WHD Day of week (MON,TUES,WED,THU,FRI,SAT,SUN)  
 DAY Day of month (1 to 31)  
 OUR Hour of day (0 to 23)

### INTERVAL TIME

TID Elapsed time in days (1 to 256)  
 TIH Elapsed time in hours (1 to 256)  
 TIM Elapsed time in minutes (1 to 256)  
 TIS Elapsed time in seconds (1 to 256)  
 T.S. Elapsed time in 1/10 of seconds (1 to 25.6)

## DESCRIPTIONS OF ERROR MESSAGE CODES

1	COMMAND NAME NOT FOUND OR NOT YET DONE	13	AX SPECIFIED WHEN NOT IN X1 OR X2 MODE
2	FORCED TO TRANSFER TO NONEXISTENT LINE	14	UNRECOGNIZABLE RELATIONAL IN ANALOG SPEC
3	REMOVED STOP FROM NONEXISTENT LINE	15	INCORRECT VALUE IN ANALOG SPECIFICATION
4	DID NOT HAVE SLASH IN STOP	16	TOO MANY ANALOG SPECIFICATIONS FOR BUFFER
5	OUTPUTTED LINE // REFERS TO NONEXISTENT LN	17	ALPHA ARGUMENT NOT FOUND IN TABLE
6	ASKED TO FIND NONEXISTENT LINE //	18	NUMERIC ARGUMENT 65K
7	VALUE OUT OF RANGE IN COMMAND LINE	19	BAD DELIMETER BETWEEN ARGUMENTS
8	OPEN OF NEW LINE BUT NO LINE NUMBER	20	BAD FIRST-DIGIT OF LINE NUMBER
9	LINE NUMBER NOT VALID	21	MULTIPLE XE ADDRESSES FOR SAME DRUM
10	EDIT COMMAND SPECIFIED, BUT NOT IN EDIT	22	NEW LINE REQUESTED, BUT MEMORY FULL
11	INPUT SETTINGS SPECIFIED IN X1 OR X2 MODE	23	CAN'T PUNCH WHILE STILL IN EDIT
12	X1 OR X2 ADDRESS IS FOR DIFFERENT DRUM	24	INVALID DRUM NUMBER

APPENDIX B

CIRCUIT SETTER VALVE OPERATION



The Circuit Setter Valve Operation Bulletin A507 has been deleted because it was copyrighted 1969, 1973 by International Telephone and Telegraph Corporation. For information contact Bell & Gossett, Fluid Handling Division - ITT, Morton Grove, Ill., 60053.

CIRCUIT SETTER  
PRE-SET BALANCE  
PROCEDURE

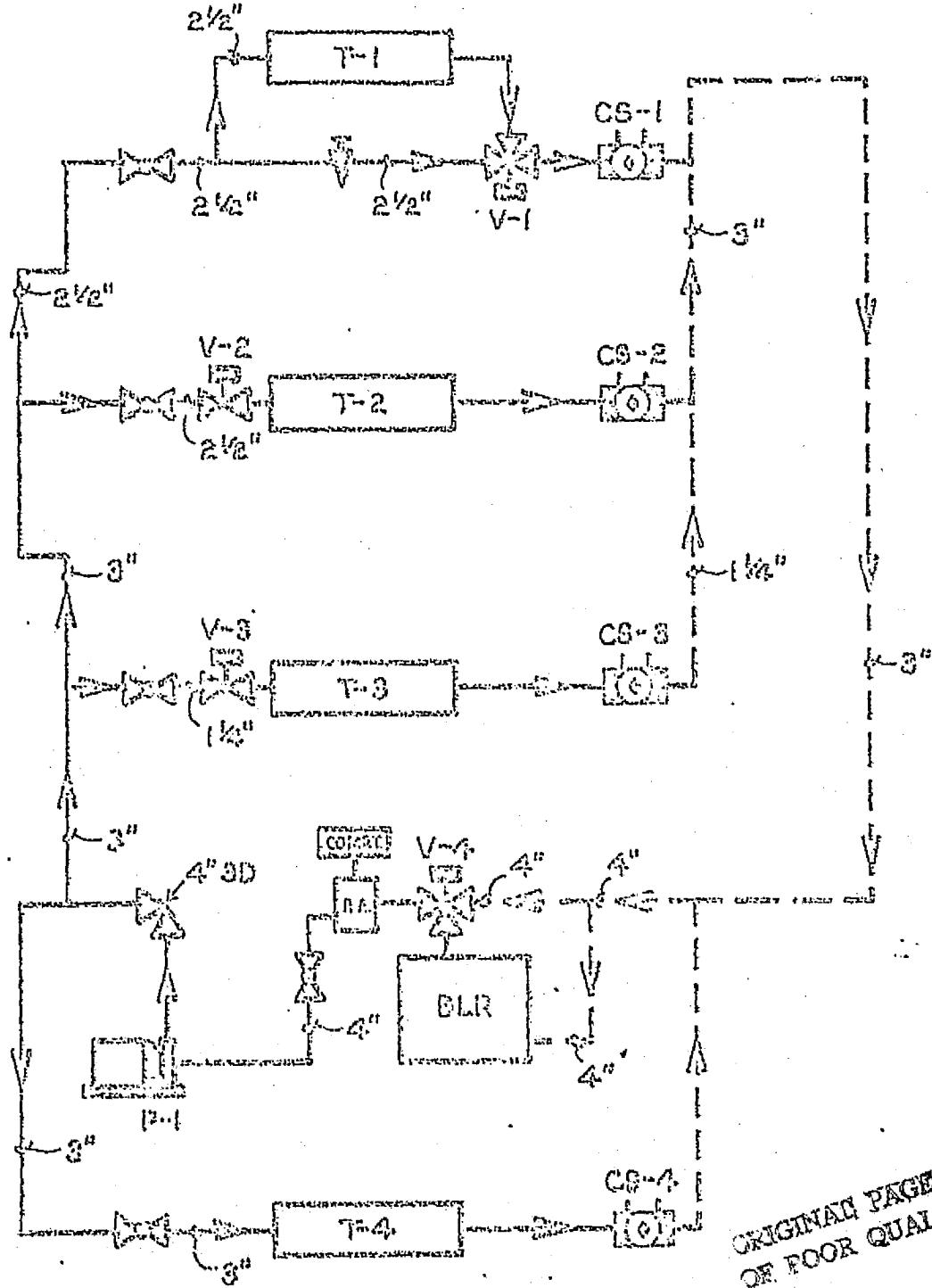


FIGURE 1. EXAMPLE BALANCE PROBLEM

NOTES:




 Indicates Gate Valve  
  Indicates Non-Calibrated Cock  
  CS Indicates Line Sized Circuit Setter

Figure 1 is representative of a "to scale" piping layout and equipment schedule as provided by a consultant's office. Figure 1 will be used as an example to illustrate pre-set balance procedure.

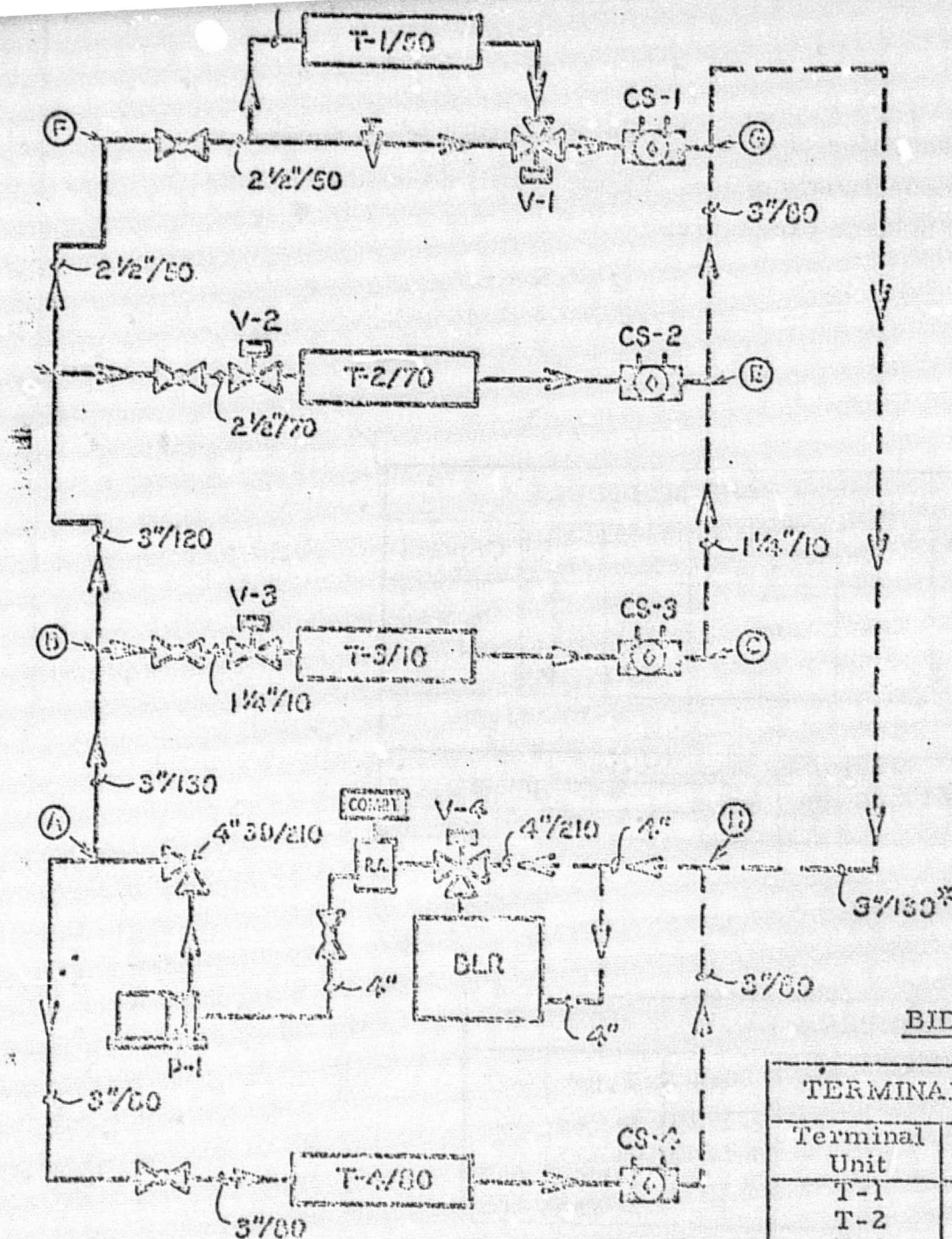
TERMINAL UNIT SCHEDULE					
Terminal Unit	Mfg. & No.	MBH Capacity	GPM Flow	Ft. Hd.	Control
T-1	--	--	50	6'	3-Way
T-2	--	--	70	12'	2-Way
T-3	--	--	10	3'	2-Way
T-4	--	--	80	4'	F&B
PUMP SCHEDULE					
Pump No.	Mfg. No.	GPM	Ft. Hd.	HP	
P-1	B&G	210	80		

CONTROL VALVE SCHEDULE				
Valve No.	Mfg.	Size	Type	Cv*
V-1	--	2-1/2"	3-Way	24
V-2	--	2-1/2"	2-Way	24
V-3	--	1-1/4"	2-Way	6.7
V-4	--	4"	3-Way	185

\*Cv often not shown, but generalized head loss limitation is stated in specification.

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\*3"/130 Means:

3" Pipe @ 130 GPM  
For Pipe Section G-H

BID SELECTED

TERMINAL UNIT SCHEDULE				
Terminal Unit	Mfg. No.	MBH	GPM	Fl. Hd.
T-1	--	--	50	--
T-2	--	--	70	--
T-3	--	--	10	--
T-4	--	--	80	--

FIGURE 2. PIPE SIZING IDENTIFICATION/FLOW RATE

#### PIPE SECTION FLOW DETERMINATION

Terminals T-1 (50 GPM) and T-2 (70 GPM) draw their required flow from the tee located at "D". Since (50 + 70) or 120 GPM leaves "D", 120 GPM must enter through pipe section B-D.

The tee located at "D" must provide 120 GPM to B-D plus 10 GPM to T-2; section A-B must then flow 130 GPM to "B". ETC.

## STEP 1

## IDENTIFY PIPE SECTIONS AND PIPE SECTION FLOW RATES

Pipe sections are letter identified from "tee to tee" as shown on Figure 2.

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Pipe section flow rates are derived from terminal unit flow rate needs and on the simple premise that water flow into a tee equals water flow away from the tee. The procedure is shown on Figure 2.

The method\* used for determining terminal unit flow rate need should be established by the consulting firm; either in the specifications or by confirmation letter to those concerned with balance. In this case, a "bid accepted" terminal unit schedule will be used.

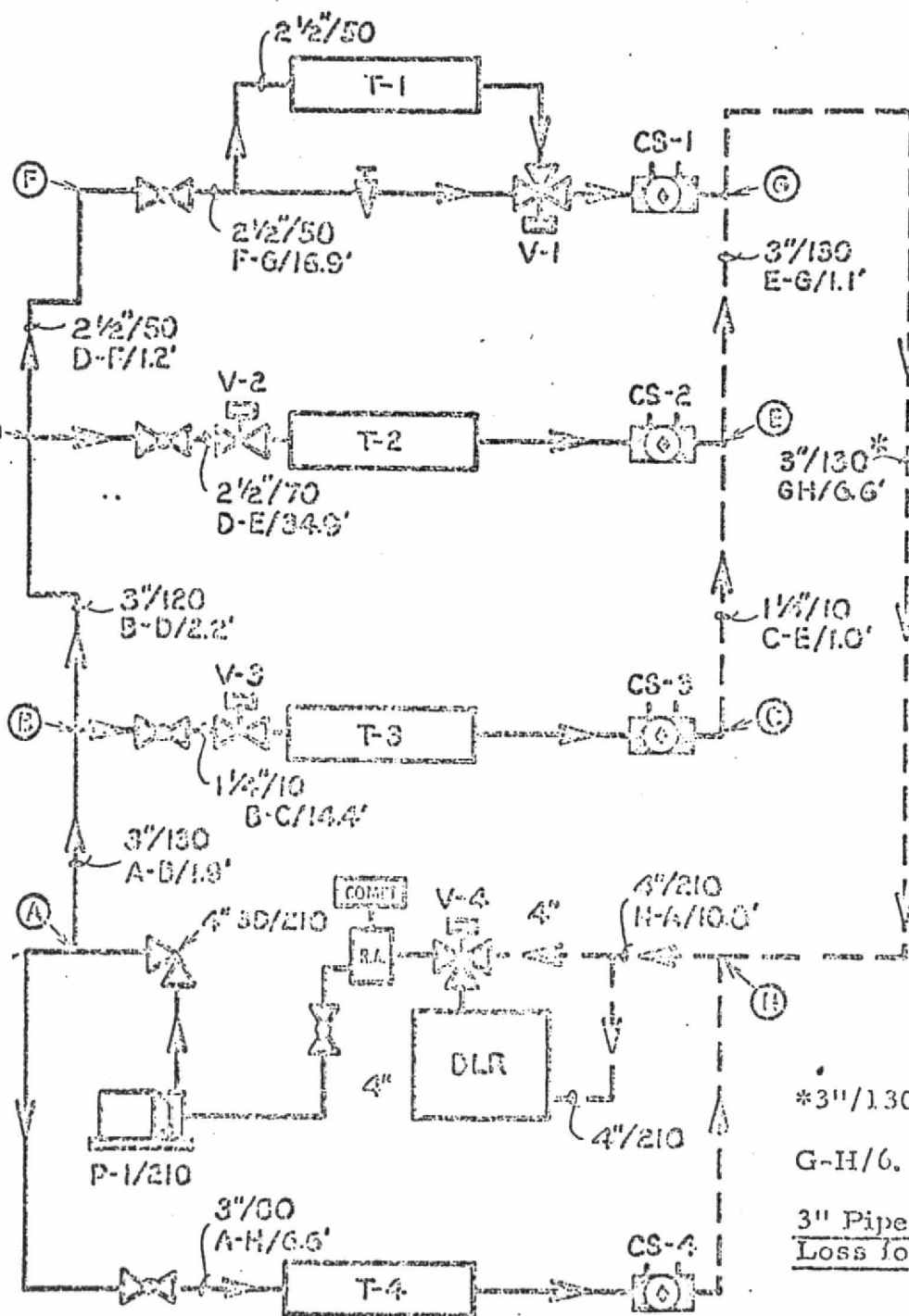
It will be noted that the schedule shown on the plan illustrates the terminals used as a basis for design; pipe sizing, etc. ... while the specification may state alternative units which are "bid acceptable".

Should another manufacturer's terminal units be accepted, the terminal unit schedule shown on the plans should be disregarded and replaced by a schedule illustrating the terminals that will actually be used.

For this example, the terminal units schedule on the plans are also "bid accepted" and form the basis for the pipe section flow rates shown on Figure 2.

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\*Other methods; GPM by temperature difference and GPM by unit size are shown in Examples 2 & 3.



\*3"/130

G-H/6.6' Means:

3" Pipe @ 130 GPM with 6.6' Hd.  
Loss for Pipe Section G-H

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FIGURE 3. PIPE SECTION HEAD LOSS SHOWN ON PLAN

**STEP 2****DETERMINE ESTIMATE PIPE SECTION HEAD LOSS BY  
TABULATED PROCEDURE AND SHOW ON PLAN**

The procedure used for determining pipe section loss (ft. Hd.) has been simplified by Bell & Gossett through use of Tables and Charts. (See Section 2; Head Loss Estimation).

In order to establish basic pre-set balance procedure most quickly, it will be assumed that pipe section head loss have been estimated\* by simple procedures later shown and that these sectional head losses appear as below:

PIPE SECTION	FLOW RATE	ESTIMATED HEAD LOSS*
A B	130	1.9'
B D	120	2.2'
D F	50	1.2'
C E	10	1.0'
E G	80	1.1'
G H	130	6.6'
F G (T <sub>1</sub> )	50	16.9'
D E (T <sub>2</sub> )	70	34.9'
B C (T <sub>3</sub> )	10	14.4'
A H (T <sub>4</sub> )	80	6.6'
H A (Equip. Room)	210	10.8'

These estimated head losses are shown on the piping plan.

\*Pipe section head loss estimation for this particular example is shown in Section 2; Head Loss Estimation; Example 1.



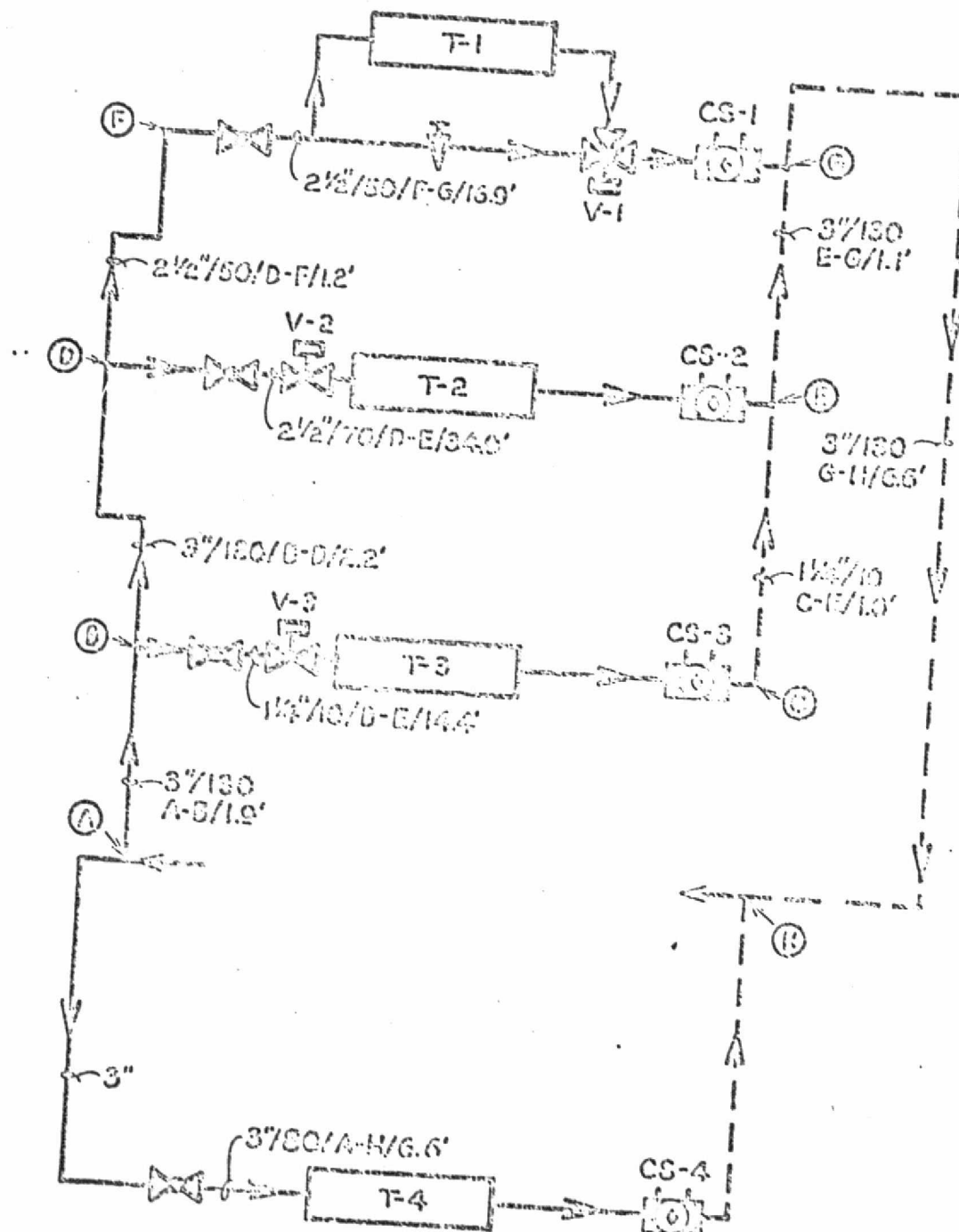


FIGURE 4. HIGHEST HEAD LOSS CIRCUIT,  
A-H Through T-2 @ 45.7'

**STEP 3****USING PIPING PLAN AS "ROAD MAP", FIND HIGHEST HEAD LOSS CIRCUIT**

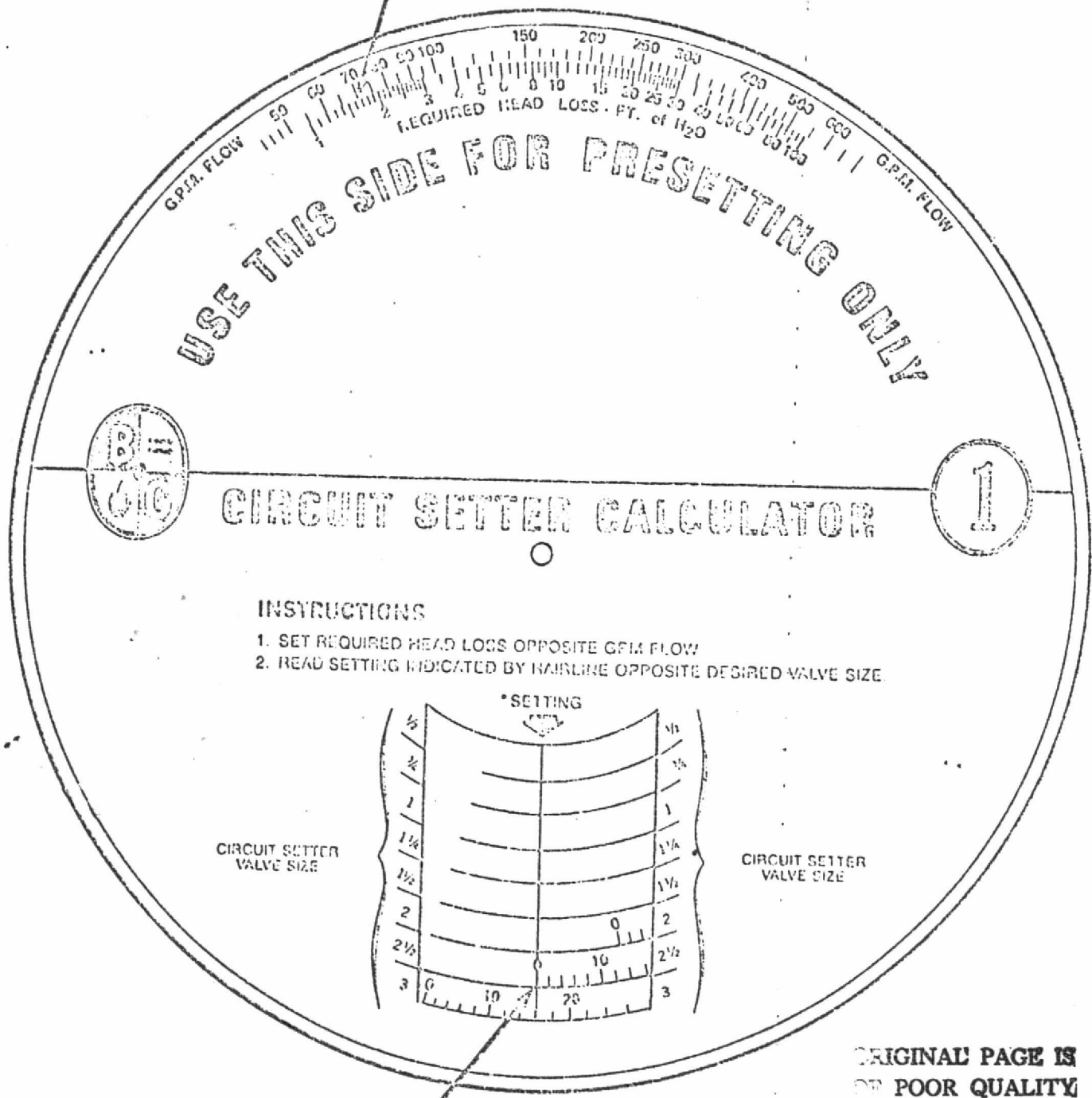
Since the equipment room piping (H→A) flows all the water delivered to the terminal circuits, it is not part of the proportional balance problem. The considerations pertaining to proportional balance start at the first junction take-off from the supply main (in Figure 4 at A) and end at the last circuit return to the return main (in Figure 4 at H).

The pipe plan is now used as a road map and all possible flow paths from A to H through the various terminal units are determined. Pipe section head loss for each possible circuit flow path are added.

The circuit flow path that has the highest head loss is found by comparison. For this example, the circuit flow path from A→H through terminal T-2 has the highest head loss as shown in the comparison below:

CIRCUIT	A H Thru T-1		A H Thru T-2		A H Thru T-3		A H Thru T-4	
	Pipe Section	Head Loss	Pipe Section	Head Loss	Pipe Section	Head Loss	Pipe Section	Head Loss
	A-B	1.9'	A-B	1.9'	A-B	1.9'	A-H (T <sub>4</sub> )	6.6'
	B-D	2.2'	B-D	2.2'	B-C (T <sub>3</sub> )	14.4'		
	D-F	1.2'	D-E (T <sub>2</sub> )	34.9'	C-E	1.0'		
	F-G (T <sub>1</sub> )	16.9'	E-G	1.1'	E-G	1.1'		
	G-H	6.6'	G-H	6.6'	G-H	6.6'		
Total Required Circuit Hd. Loss		28.8'		45.7'		25.0'		6.6'
Highest Hd. Loss		————→		45.7'				

STEP 2: READ 1.7' HEAD LOSS OPPOSITE  
70 GPM FLOW RATE



STEP 1: SET RULE (SIDE 1) TO OPEN (0°)  
SETTING FOR 2½" VALVE

FIGURE 5.

FIND OPEN CIRCUIT SETTER VALVE  
HEAD LOSS

STEP 3a

FIND BALANCE GOVERNING HEAD LOSS; ADD OPEN CIRCUIT SETTER HEAD LOSS TO HIGH HEAD LOSS CIRCUIT

The highest head loss circuit (A→H thru T<sub>2</sub>) includes an open circuit setter valve (CS-2) in pipe section D-E. The head loss of this valve must be added to its circuit head loss to establish the balance governing head loss.

The open circuit setter valve is contained in pipe section D-E; which is abstracted from Figure 4 as below:

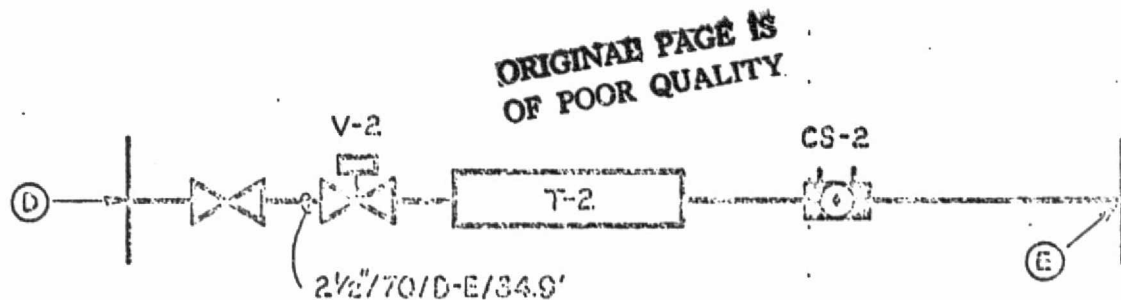


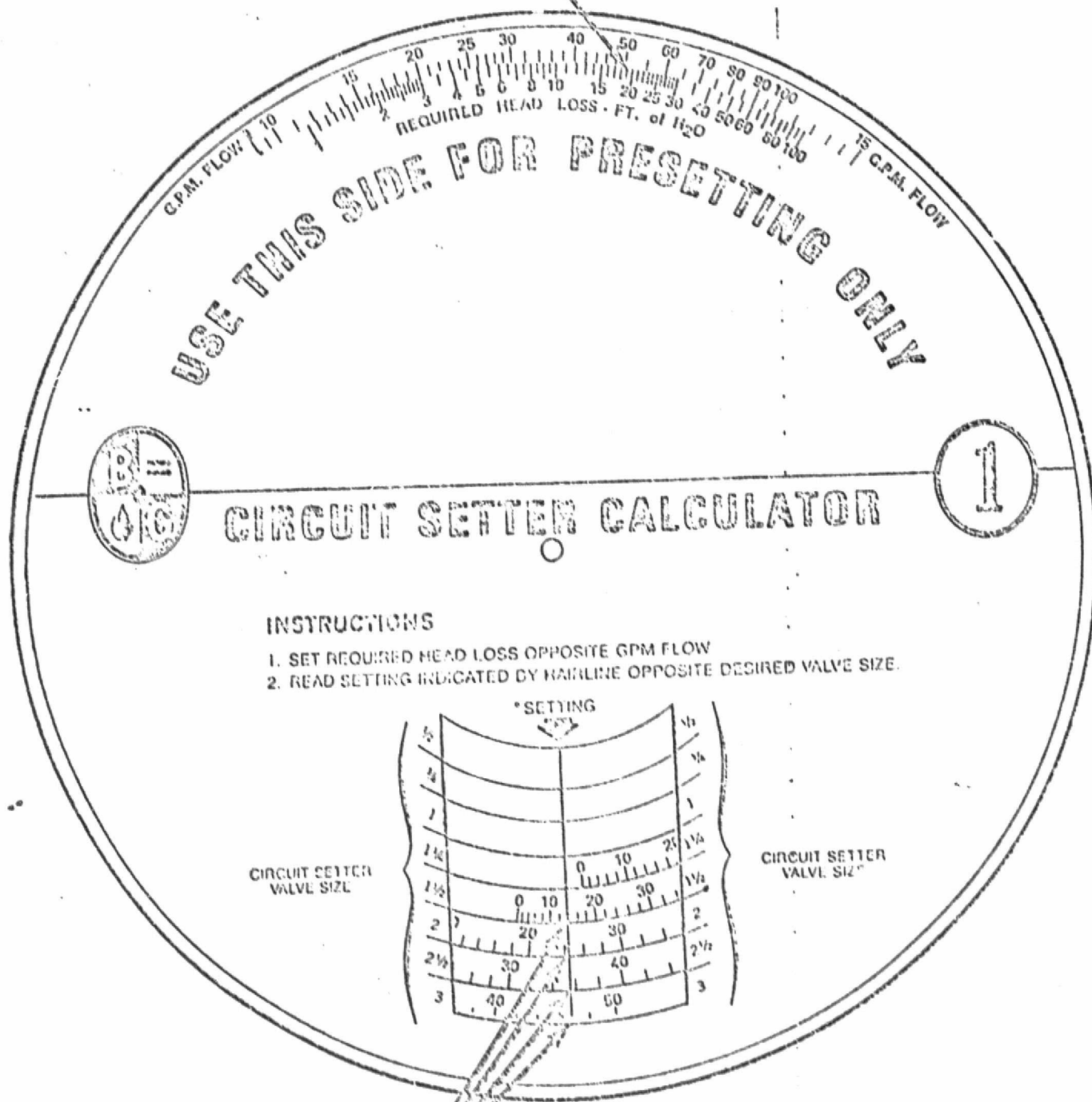
FIGURE 5a. SECTION D-E ABSTRACTED FROM FIGURE 4.

The open circuit setter valve is line-sized at 2-1/2" and flows 70 GPM. Figure 5 shows that for this condition, the circuit setter valve will cause 1.7' head loss.

Balance governing head loss now becomes:

HIGHEST CIRCUIT HEAD LOSS (A→H thru T <sub>1</sub> )	=	45.7'
OPEN 2-1/2" CIRCUIT SETTER @ 70 GPM	=	<u>1.7'</u>
TOTAL <u>BALANCE GOVERNING HEAD LOSS</u>	=	47.4'

STEP 1: SET FOR SELECTION CONDITIONS:  
50 GPM @ 18.6' FOR CS-1



STEP 2: READ POSSIBLE SELECTIONS FOR  
CONDITIONS 50 GPM 18.6'

1 1/2" @ 14°  
2" @ 24°  
2 1/2" @ 36°  
3" @ 47°

FIGURE 6.

SELECTION FOR CS-1; 2-1/2" LINE-SIZED  
CIRCUIT SETTER @ 36 USED

**STEP 4****DETERMINE "PRE-SET" CIRCUIT HEAD LOSS REQUIREMENT  
AND CIRCUIT SETTER SETTING EQUIVALENT**

The piping layout shown in Figure 4 will be set in proportional flow balance when each separate flow-circuit path has equal head loss at its design flow rate.

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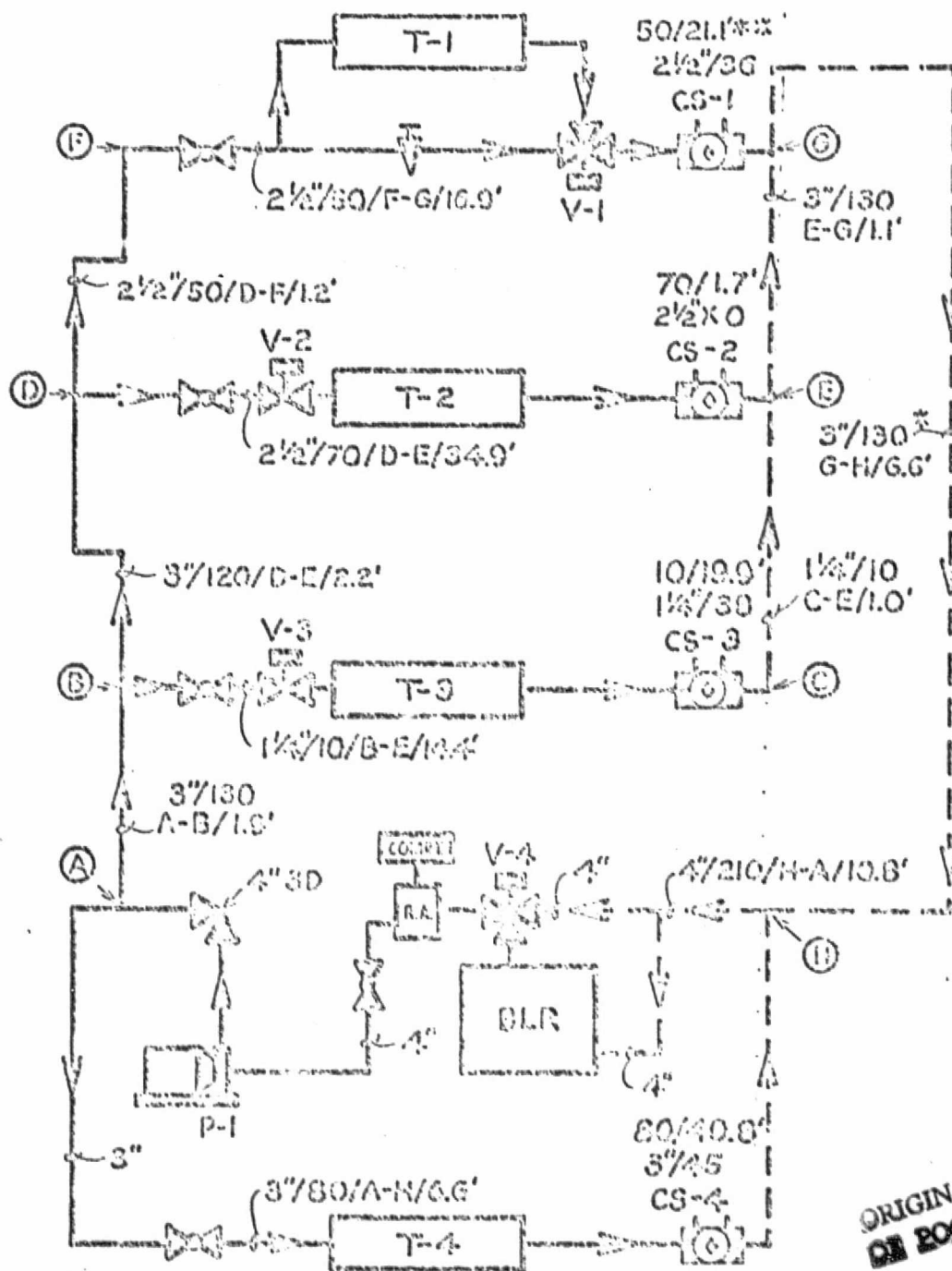
In order to achieve this objective, circuit setter valves will be "pre-set" for the head loss difference between that needed for the "balance governing" circuit and the "total required) head loss for all other circuits. This can be tabulated as below:

CIRCUIT	A→H thru T <sub>1</sub>	A→H thru T <sub>2</sub>	A→H thru T <sub>3</sub>	A→H thru T <sub>4</sub>
"Balance Governing" Head Loss	47.4'	47.4'	47.4'	47.4'
Total Required Head Loss/Circuit	-28.8'	-45.7'	-25.0'	-6.6'
Circuit Head Loss Difference	18.6'	1.7'	22.4'	40.8'
Circuit Setter Flow	50 GPM	70 GPM	10 GPM	80 GPM
Circuit Setter No.	CS-1	CS-2	CS-3	CS-4
Circuit Setter Pre-set	18.6' @ 50 GPM	1.7' @ 70 GPM	22.4' @ 10 GPM	40.8' @ 80 GPM

The circuit setter valves are selected for the conditions shown in the last tabulated line. The procedure for selection is shown in Figure 6 for CS-1

While circuit setter valves will often be selected smaller than line-size, for this example a line-size selection is made as follows:

CIRCUIT SETTER NO.	CS-1	CS-2	CS-3	CS-4
VALVE SIZE	2-1/2"	2-1/2"	1-1/4"	3"
SETTING	36°	Open (0)	39°	45°



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FIGURE 7. FINAL PIPE LAYOUT PLAN SHOWING CIRCUIT SETTER SETTINGS FOR PROPORTIONAL FLOW BALANCE

\*3"/130/G-H/6.6' Means:

3" Pipe, 130 GPM, G-H Head Loss = 6.6'

\*\*50/21.1'/2-1/2"/36°/CS-1... Means:

50 GPM @ 21.1 Ft. Hd., 2-1/2" Circuit Setter @ 36° for CS-1

APPENDIX C

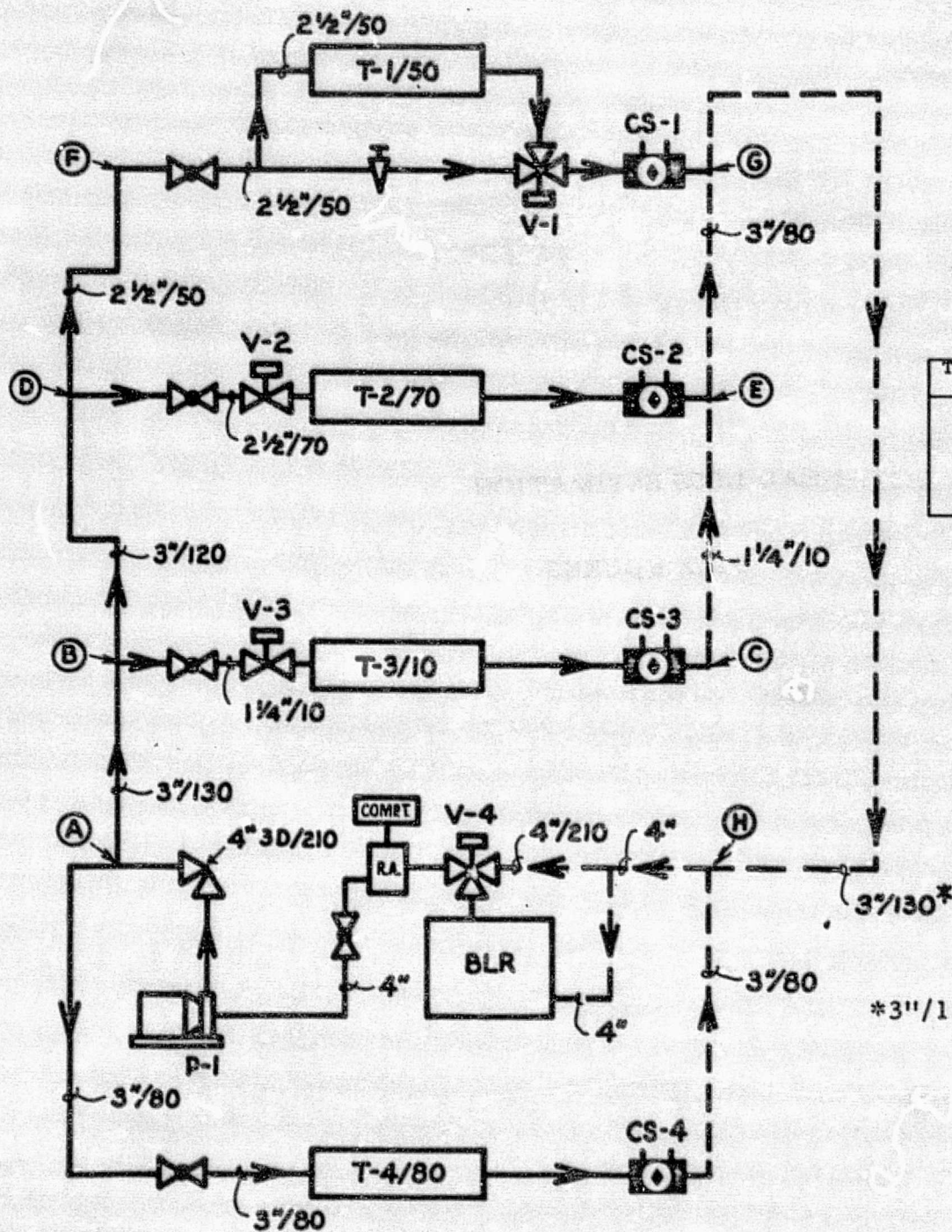
PUMP MAINTENANCE



The Series "60" In-line Centrifugal Pump Maintenance Instruction Sheet S16946, Parts List and Performance Curves have been deleted because they were copyrighted in 1967, 1974, 1975, and 1976 by International Telephone and Telegraph Corporation. For information contact Bell & Gossett, Fluid Handling Division - ITT, Morton Grove, Ill., 60053.

HEAD LOSS ESTIMATION

PROCEDURES



BID SELECTED  
TERMINAL UNIT SCHEDULE

Terminal Unit	Mfg. No.	MBH	GPM	Ft. Hd.
T-1	--	---	50	--
T-2	--	---	70	--
T-3	--	---	10	--
T-4	--	---	80	--

\*3" / 130 Means:

3" Pipe @ 130 GPM  
For Pipe Section G-H

FIGURE 1. EXAMPLE BALANCE PROBLEM

## HEAD LOSS ESTIMATION PROCEDURES

Pre-set balance procedures require that each pipe section be evaluated in terms of its head loss. For purposes of evaluation, system piping sections can be broken into three types:

1. Distribution Pipe Sections

The distribution pipe sections are the supply and return pipe sections between the equipment room and the terminal unit pipe circuits. Distribution pipe sections are exemplified in Figure 1, page 42, by pipe sections A-B, B-D, D-F, C-E, E-G and G-H. Distribution pipe sections usually contain only pipe length, elbows and tees.

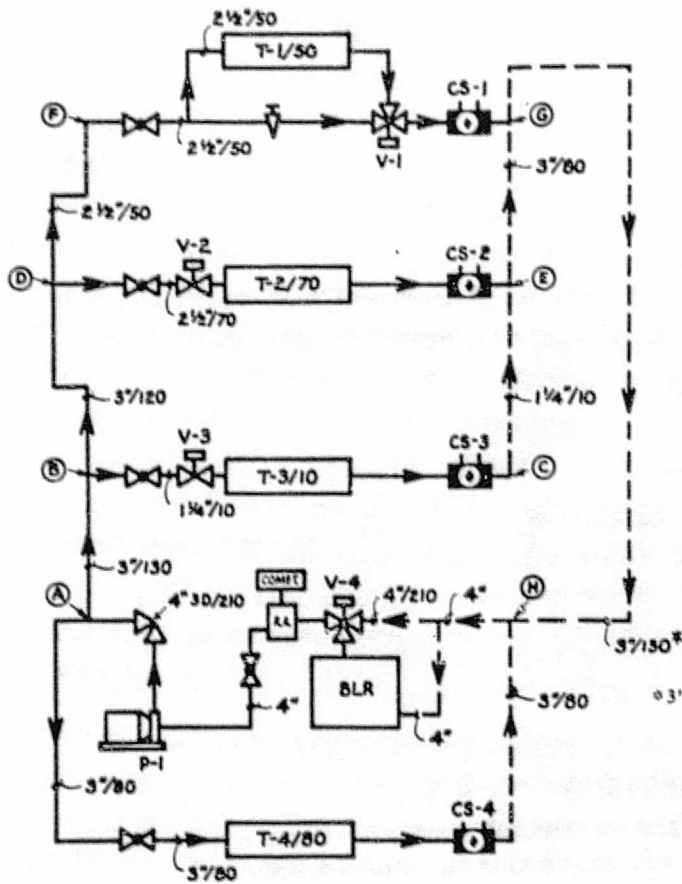
2. Terminal Sub-Circuit Pipe Section

The "sub-circuit" contains the terminal unit and its control valve (if used) together with shut-off valves, etc. and is exemplified in Figure 1, page 42, by pipe sections B-C (thru T<sub>3</sub>), D-E (Thru T<sub>2</sub>), F-G (thru T<sub>1</sub>) and A-H (thru T<sub>4</sub>).

3. Equipment Room Pipe Section

The equipment room pipe section flows total system flow rate and is exemplified in Figure Figure 1, page 42, by section H-A (thru boiler, etc.). Equipment room pipe section head loss is not necessary for proportional pre-set balance, but is useful for final flow estimation.

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Distribution Pipe Section	Measured Length
A-B	30'
B-D	40'
D-F	42'
C-E	50'
E-G	60'
G-H	132'

3\"/>

3\"/>

FIGURE 2

DISTRIBUTION PIPE SECTIONS REPRESENTED BY SECTIONS A-B, B-D, D-F, C-E, E-G AND G-H

### Distribution Pipe Section Head Loss Tabulation Form

Pipe Section	A-B	B-D	D-F	C-E	E-G	G-H
Flow Rate	130	120	50	10	80	130
Pipe Size	3"	3"	2 1/2"	1 1/4"	3"	3"
Measured Length	30'	40'	42'	50'	60'	132'
Equivalent Length (Table 2)	El or Thru Tee	24'	18'	3 1/2'	8'	32'
	Side Tee	16'				
	Valve					
	Other					
	Other					
Total Equivalent Length	46'	64'	60'	53 1/2'	68'	164'
Pipe & Fitting Head Loss (Table 1)	1.9'	2.2'	1.2'	1.0'	1.1'	6.6'

### WORKSHEET 1



### ESTIMATING DISTRIBUTION PIPE SECTION HEAD LOSS

Actual estimation of pipe section head loss is best explained by reference to the examples stated for use with the head loss estimation table (Table 1 - page C-8). The examples used are for pipe sections A-B and B-D in Figure 2, page C-6.

Table 1 stated the relationships between pipe size, pipe flow and piping head loss as affected by total equivalent pipe length (TEL). Since pipe size and flow rate is known, the balance contractor need only establish TEL to determine pipe section head loss.

TEL will be the sum of measured (scaled) pipe length plus the equivalent fitting length as shown on Table 2, page C-9.

Reference to the examples stated for the head estimation tables illustrate such procedural simplicity that tabulation forms (though shown in worksheet 1, page C-6 are not needed. Head loss results can be directly entered on the plans since only a simple addition (measured plus fitting equivalent length) permits entry into Table 1.

### NOTES CONCERNING DISTRIBUTION PIPE SECTION HEAD LOSS







Distribution piping will commonly occur as between two tees; see section B-D (Figure 2, page C-6). When estimating distribution piping fitting equivalent length, however, only one tee is used for estimation (as at "B" in pipe section B-D). This is because the tee at "D" will be included in the evaluation for pipe section D-F.

TABLE 1 FT. HEAD LOSS ESTIMATION TABLE

TABLE 1 FT. HEAD LOSS ESTIMATION TABLE

PIPE LENGTH, FT.													PIPE LENGTH, FT.												
.1	12.5	10	8.3	7.1	6.25	5.5	5	4.5	4.2	3.8	3.6	3.3	3.1	2.9	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2	.1		
.2	25	20	16.6	14.3	12.5	11.1	10	8.1	8.3	7.7	7.2	6.6	6.2	5.9	5.5	5.2	5	4.7	4.5	4.3	4.1	4	.2		
.3	37.5	30	25	21.4	18.7	16.6	15	13.6	12.5	11.6	10.7	10	9.3	8.8	8.3	7.9	7.5	7.1	6.8	6.5	6.2	6	.3		
.4	50	40	33.3	28.6	25	22.2	20	18.2	16.6	15.3	14.3	13.3	12.5	11.7	11.1	10.5	10	9.5	9.0	8.7	8.3	8	.4		
.5	62.5	50	41.6	35.7	31.2	27.7	25	22.7	20.8	19.2	17.9	16.6	15.6	14.7	13.8	13.1	12.5	11.9	11.3	10.8	10.4	10	.5		
.6	75	60	50	42.8	37.4	33.2	30	27.2	25	23.2	21.4	20	18.7	17.6	16.6	15.7	15	14.3	13.6	13	12.5	12	.6		
.7	87.5	70	58.3	50	43.7	38.8	35	31.8	29.1	26.9	25	23.3	21.8	20.5	19.4	18.4	17.5	16.7	15.9	15.2	14.6	14	.7		
.8	100	80	66.6	57.2	50	44.4	40	36.4	33.2	30.6	28.6	26.6	25	23.4	22.2	21	20	19	18.2	17.4	16.6	16	.8		
.9	112.5	90	75	64.3	56.2	50	45	40.9	37.4	34.5	32.1	30	28.1	26.4	25	23.6	22.5	21.4	20.7	19.5	18.7	18	.9		
1.0	125	100	83.3	71.4	62.4	55.5	50	45.4	41.6	38.4	36.7	33.3	31.2	29.4	27.7	26.2	25	23.8	22.3	21.6	20.8	20	1.0		
1.1	137.5	110	91.3	78.5	68.6	60.9	55	49.9	45.0	42.4	40	36.6	34.3	32.3	30.4	28.9	27.5	26.2	24.9	23.8	22.9	22	1.1		
1.2	150	120	100	85.6	74.8	66.4	60	54.4	50	46.4	44.4	40	37.8	35.2	33.2	31.4	30	28.6	27.2	26	25	24	1.2		
1.3	162.5	130	108.3	92.8	81.1	72	65	59	54.1	50	46.4	43.3	40.6	38.1	36	34.1	32.5	31	29.5	28.2	27	26	1.3		
1.4	175	140	116.6	100	87.4	77.6	70	63.6	58.2	53.8	50	46.6	43.7	41	38.8	36.8	35	33.4	31.8	30.4	29.1	28	1.4		
1.5	187.5	150	125	107.2	93.7	83.2	75	68.2	62.3	57.5	53.6	50	46.9	43.9	41.6	39.4	37.5	35.7	34.1	32.6	31.1	30	1.5		
1.6	200	160	133.3	114.4	100	88.8	80	72.8	66.4	61.2	57.2	53.3	50	46.8	44.4	42	40	38	36.4	34.8	33.2	32	1.6		
1.7	212.5	170	141.6	121.5	106.2	94.4	85	77.3	70.6	65.1	60.7	56.6	53.1	50	47.2	44.6	42.5	40.4	38.7	36.9	35.3	34	1.7		
1.8	225	180	150	128.6	112.4	100	90	81.8	75	69	64.3	60	56.2	52.8	50	47.2	45	42.4	40.9	39	37.5	36	1.8		
1.9	237.5	190	158.3	135.7	118.6	105.5	95	86.3	79	72.9	67.9	63.3	59.3	55.8	52.7	50	47.5	45.2	43.1	41.1	39.5	38	1.9		
2.0	250	200	166.6	142.8	124.8	111	100	90.8	83.2	76.8	71.4	66.6	62.4	58.8	55.5	52.4	50	47.6	45.4	43.2	41.6	40	2.0		
2.1	262.5	210	175	150	131	116.4	105	95.3	87.4	80.8	75	70	65.5	61.7	58.7	55.1	52.5	50	47.7	45.4	43.7	42	2.1		
2.2	275	220	183.3	157.1	137.2	121.8	110	100	91.6	84.8	78.6	73.3	68.6	64.6	60.9	57.8	55	52.4	50	47.6	45.8	44	2.2		
2.3	287.5	230	191.3	164.1	143.4	127.3	115	104.3	95.8	88.8	82	76.6	71.7	67.5	63.6	60.3	57.5	54.8	52.1	50	47.9	46	2.3		
2.4	300	240	200	171.2	149.6	132.8	120	108.3	100	92.8	85.6	80	74.8	70.4	66.4	62.8	60	57.2	54.4	52	50	48	2.4		
2.5	312.5	250	208.3	178.4	155.9	138.4	125	113.4	104.1	96.4	89.2	83.3	77.9	73.3	69.2	65.5	62.5	59.6	56.7	54.2	52	50	2.5		
2.6	325	260	216.6	185.6	162.2	144	130	118	108.2	100	92.8	86.6	81.1	76.2	72	68.2	65	62	59	56.4	54.1	52	2.6		
2.7	337.5	270	225	192.8	168.5	149.6	135	122.6	112.3	103.8	96.4	90	84.3	79.1	74.8	70.9	67.5	64.4	61.3	58.6	56.1	54	2.7		
2.8	350	280	233.3	200	174.8	155.2	140	127.2	116.4	107.6	100	93.3	87.4	82	77.6	73.6	70	66.8	63.6	60.4	58.2	56	2.8		
2.9	362.5	290	241.6	207.2	181.1	160.8	145	131.8	120.5	111.3	103.6	96.6	90.5	84.9	80.4	76.2	72.5	69.1	65.9	63	60.2	58	2.9		
3.0	375	300	250	214.4	187.4	166.4	150	136.4	124.6	115	107.2	100	93.7	87.8	83.2	78.8	75	71.4	68.2	65.2	62.3	60	3.0		
3.2	400	320	258.3	228.8	200	177.6	160	145.6	132.8	122.4	114.4	106.6	100	93.6	88.8	84	80	75.7	72.8	69.4	66.4	64	3.2		
3.4	425	340	283.2	250	212.4	188.8	170	154.6	141.2	130.4	125	113.2	106.2	100	94.4	89.2	85	80.8	77.3	73.8	70.6	68	3.4		
3.6	450	360	300	257.2	224.8	200	180	163.6	150	138	128.6	126.6	118.6	111.6	105.5	100	95	90.4	86.3	82.2	79	76	3.6		
3.8	475	380	316	271.4	237.2	211	190	172.6	158	145.8	135.7	133.2	124.8	117.6	111	104.8	100	95.2	90.8	86.4	83.2	80	4.0		
4.0	500	400	333	285.6	249.6	222	200	181.6	166.4	153.6	142.8	140	131	123.4	116.2	110.2	105	100	95.3	90.8	87.4	84	4.2		
4.2	525	420	350	300	262	232.4	210	190.6	174.8	161.6	150	140	131	123.4	116.2	110.2	105	100	95.3	90.8	87.4	84	4.2		
4.4	550	440	366	314.2	274.4	243.6	220	200	183.2	169.6	157.1	146.6	137.2	129.2	121.8	115.6	110	104.8	100	95.2	91.6	88	4.4		
4.6	575	460	379	328.2	286.8	254.6	230	208.6	191.6	177.6	164.1	153.2	143.4	135	127.3	120.6	115	109.6	104.3	100	95.8	92	4.6		
4.8	600	480	400	342.4	299.2	265.6	240	217.6	200	185.6	171.2	160	150	140.8	132.8	125.6	120	114.4	108.8	104	100	96	4.8		
5.0	625	500	416	357	312	278	250	226.8	208.2	192.8	178.5	166.6	156	146.6	139	131	125	119.2	113.4	108.4	104.1	100	5.0		
Friction (ft.)																									
GPM																									
3/8	--	.46	.51	.55	.6	.63	.67	.7	.74	.76	.8	.84	.86	.89	.92	.95	.97	1	1.02	1.05	1.07	1.1	3/8		
1/2	.76	.86	.95	1.07	1.12	1.2	1.27	1.33	1.4	1.46	1.52	1.59	1.62	1.68	1.75	1.8	1.85	1.9	1.95	2	2.04	2.08	1/2		
3/4	1.62	1.85	2	2.2	2.4	2.55	2.7	2.85	2.95	3.1	3.22	3.35	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	3/4		
1	3.1	3.5	3.9	4.3	4.55	4.8	5.2	5.4	5.7	5.9	6.2	6.4	6.6	6.9	7.1	7.3	7.5	7.7	7.9	8.1	8.3	8.4	1		
1-1/4	6.6	7.2	8.2	9.6	10.5	10.75	11.2	11.8	12.5	13	13.4	13.8	14.2	14.8	15	15.5	16	16.4	16.8	17.2	17.5	17.8	1-1/4		
1-1/2	9.8	11.1	12.2	13.3	14.2	15.1	16	17	17.8	18.5	19.2	20	20.8	21.4	22	22.8	23.4	24.2	24.8	25.4	26	26.5	1-1/2		
2	19.2	21.5	24	26	28	29.8	31.5	33	34.5	36	37.5	39	40.5	42	43	44	45	46	47	48	50	51	2		
2-1/2	30.5	35	38	42	44	47	50	53	56	58	60	62.5	65	67	69	71	73	75	77	78	80	82	2-1/2		
3	55	63	69	75	80	85	90	95	100	105	110	114	118	122	126	132	136	139	142	146	150	153	3		
4	115	128	142	153	165	175	188	198	208	215	224	233	242	250	257	265	270	278	286	296	302	306	4		
5	208	232	258	280	300	320	340	360	378	390	408	425	440	455	468	481	495	505	520	535	550	560	5		
6	335	380	420	450	490	520	550	580	610	640	670	700	720	750	7										

**TABLE 2**  
**FITTING EQUIVALENT LENGTH TABLE**

Nominal Pipe Size	90° El Or Tee; Flow Thru		Tee; Side Branch Flow In Or Out		90° Miter	45° Miter	VALVES		
							GATE	GLOBE	PLUG
	Screw	Cu Or Weld	Screw	Cu Or Weld	Weld	Weld	All	All	All
1/2"	1	1/2	2	1	2-1/2	1/2	1/2	15	1
3/4"	2	1	4	2	4	3/4	1/2	20	1-1/2
1"	3	1-1/2	6	3	5	1	3/4	25	2
1-1/4"	3-1/2	1-3/4	7	3-1/2	6	1-1/4	1	30	2-1/2
1-1/2"	4	2	8	4	7-1/2	1-1/2	1-1/4	40	3
2"	5	2-1/2	10	5	10	2	1-1/2	50	4
2-1/2"	6	3	12	6	12-1/2	2-1/2	2	80	5
3"	8	4	16	9	15	3	2-1/2	90	6
4"		5-1/2		12	20	4	3	110	8
5"		8		15	25	5	3-1/2	140	10
6"		9		18	30	6	4	170	12
8"		11		24	40	8	5	240	16
10"		15		30	50	10	7	290	20
12"		18		36	60	12	8	320	24

\*Applies to Side Branch Flow

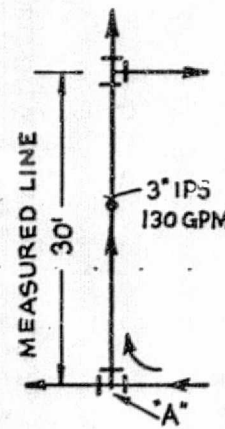
**EXAMPLE 3:**

Determine head loss for 3" pipe, 130 GPM when TEL = 164' (Section G-H, Example Problem).

**SOLUTION:**

Enter Table 1 @ 3" pipe, proceed to 130 GPM (132), proceeding upward it is found that 164' is not shown on Table.  
164' = 100' + 64' SO:

$$\begin{aligned} \text{Head Loss @ 100'} &= 4.0' \\ \text{Head Loss @ 64' (65)} &= 2.6' \\ \text{TOTAL HEAD LOSS} &= 6.6' \end{aligned}$$



**EXAMPLE 1**  
**DIAGRAM**

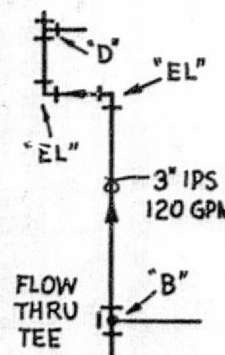
**EXAMPLE 1:**

Estimate friction loss from A to B given the following

- (1) Pipe Size is 3".
- (2) Flow is 130 GPM.
- (3) Measured length (plan) = 30'
- (4) Tee @ "A" is screwed and 3" side branch size; flow is side branch.

**SOLUTION:**

- (1) Determine Fitting Equivalent Length  
From Table 2, 3" screwed tee, side branch flow equivalent length = 16'. Do not include equivalent length for fitting @ "B".
- (2) Determine Total Equivalent Length (TEL)  
TEL = Measured Length + Fitting E. L. = 30' + 16' = 46'
- (3) Determine Friction Loss By Use of Table 1  
Enter Table 1 @ 3" I. P. S. Proceed to 130 GPM next greater (132). Proceed upward to TEL equal to or greater than 46' (47.5'). Read 1.9' friction loss (See Table 1).



**EXAMPLE 2**  
**DIAGRAM**

**EXAMPLE 2:**

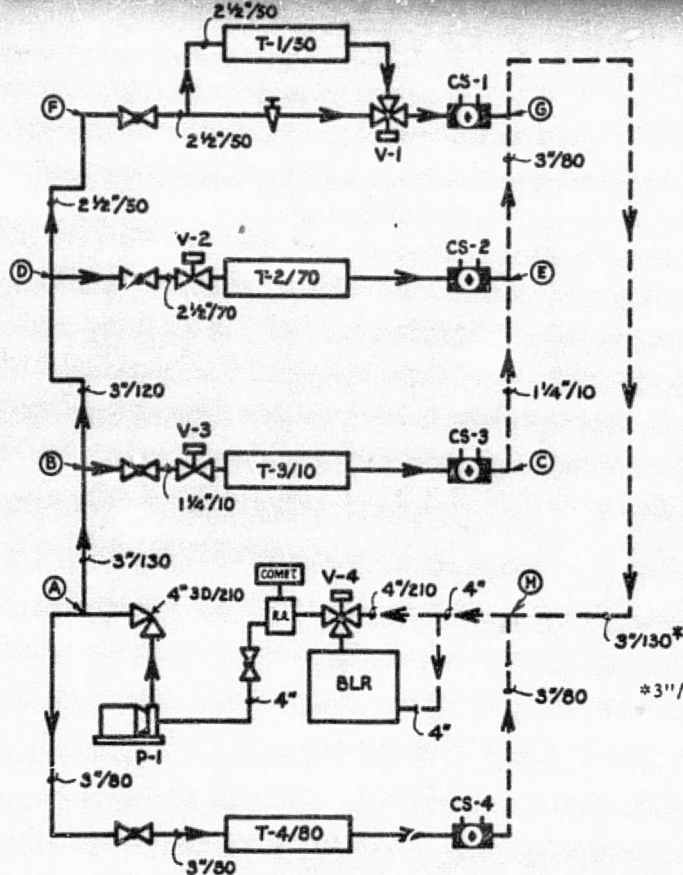
Estimate friction loss from B to D given:

- (1) Pipe Size is 3"
- (2) Flow is 120 GPM
- (3) Measured Length = 40'
- (4) Pipe Section Includes Screwed Fittings as:  
2 Els + 1 Flow Thru Tee

**SOLUTION:**

- (1) Determine Fitting Equivalent Length from Table 1  
each fitting = 8' E. L.; Fitting E. L. = 3 x 8 = 24'
- (2) Determine B-D Total Equivalent Length:  
TEL = 40' + 24' = 64'
- (3) Determine Friction Loss by use of Table 1.  
Enter @ 3" to 120 GPM (122) upward, to 64' TEL (64.6); Read 2.2' Friction Loss





# BID SELECTED

## TERMINAL UNIT SCHEDULE

Terminal Unit	Mfg. No.	MBH	GPM	Ft. Hd.
T-1	--	---	50	5'
T-2	--	---	70	12'
T-3	--	---	10	3'
T-4	--	---	80	4'

## VALVE C<sub>v</sub> SCHEDULE

Valve No.	C <sub>v</sub>	GPM
V <sub>1</sub>	24	50
V <sub>2</sub>	24	70
V <sub>3</sub>	4.8	10
V <sub>4</sub>	185	210

\*3"/130 Means:

3" Pipe @ 130 GPM  
For Pipe Section G-H

FIGURE 3

TERMINAL OR SUB-CIRCUIT PIPE SECTIONS REPRESENTED BY PIPE SECTIONS F-G (THRU T<sub>1</sub>), D-E (THRU T<sub>2</sub>), B-C (THRU T<sub>3</sub>) AND A-H (THRU T<sub>4</sub>)

## Distribution Pipe Section Head Loss Tabulation Form

Pipe Section	A-B	B-D	D-F	C-E	E-G	G-H	F-G	D-E	B-C	A-H
Flow Rate	130	120	50	10	80	130	50	70	10	80
Pipe Size	3"	3"	2 1/2"	1 1/4"	3"	3"	2 1/2"	2 1/2"	1 1/4"	3"
Measured Length	30'	40'	42'	50'	60'	132'	50'	50'	64'	110'
Equivalent Length (Table 2)	El or Thru Tee	3/24'	3/18'	1/3 1/2'	1/8'	1/32'	3/18'	1/3 1/2'	1/32'	
	Side Tee	1/16'					2/24'	2/24'	7'	1/16'
	Valve						1/2'	1/2'	1'	1/2 1/2'
	Other									
	Other									
Total Equivalent Length	46'	64'	60'	53 1/2'	68'	164'	94'	76'	75 1/2'	160 1/2'
Pipe & Fitting Head Loss (Table 1)	1.9'	2.2'	1.2'	1.0'	1.1'	6.6'	1.9'	2.9'	1.4'	2.6'
Terminal	Unit No.						T-1	T-2	T-3	T-4
	Head Loss						5'	12'	3'	4'
Control Valve	C <sub>v</sub>						24	24	4.8	—
	Head Loss						10'	20'	10'	—
Total Head Loss with Control Valve							16.9'	34.9'	14.4'	6.6'

WORKSHEET 2

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## TERMINAL SUB-CIRCUIT HEAD LOSS ESTIMATION

The terminal sub-circuits (Figure 3, page C-10) differ from the distribution piping circuits in that they contain terminal units and fittings. Head loss estimation is therefore broken into three parts:

1. Pipe and Fitting Head Loss
2. Control Valve Head Loss
3. Terminal Unit Head Loss

The total terminal or sub-circuit head loss is the summation of the head losses described as illustrated in the calculation sheet under Worksheet 2, page C-10.

Pipe and fitting head loss procedures for the terminal circuit are exactly the same as already described for the distribution pipe sections (see page C-2).

Control valve head loss determination procedures are based on " $C_v$ " description of valve capacity. While the procedure is simple, it does require separate discussion.  $C_v$  head loss procedures are described on the next pages (pages C-12, 13).

Terminal unit head losses are usually based on "Bid Selected" terminal unit manufacturer's data. Notes concerning terminal unit head loss determinates are described on the following pages.

## CONTROL VALVE HEAD LOSS: $C_v$ PROCEDURE

The temperature control contractor will provide valve  $C_v$  descriptions to the balance contractor for each control valve in the piping system.

The terminal  $C_v$  describes the valve flow-head loss relationship and means the valve flow rate that is required to cause 1 PSI or 2.3 ft. head loss across the valve. Since head loss varies as the square of the flow change, the  $C_v$  valve can be used as the base for estimating head loss for other flow rates.

Scale 5 on the B&G System Syzer has been particularly arranged for  $C_v$  head loss evaluation. To illustrate its use, the example problem will be used. The problem states that the control valves used for  $T_1$  and  $T_2$  have a  $C_v = 24$ . Flow rates are 50 GPM through  $T_1$  and 70 GPM through  $T_2$ .

For this circumstance, the  $C_v$  mark on Scale 5 is set opposite 24 GPM. Valve head loss is read opposite the specified flow rate as below in Figure 4.

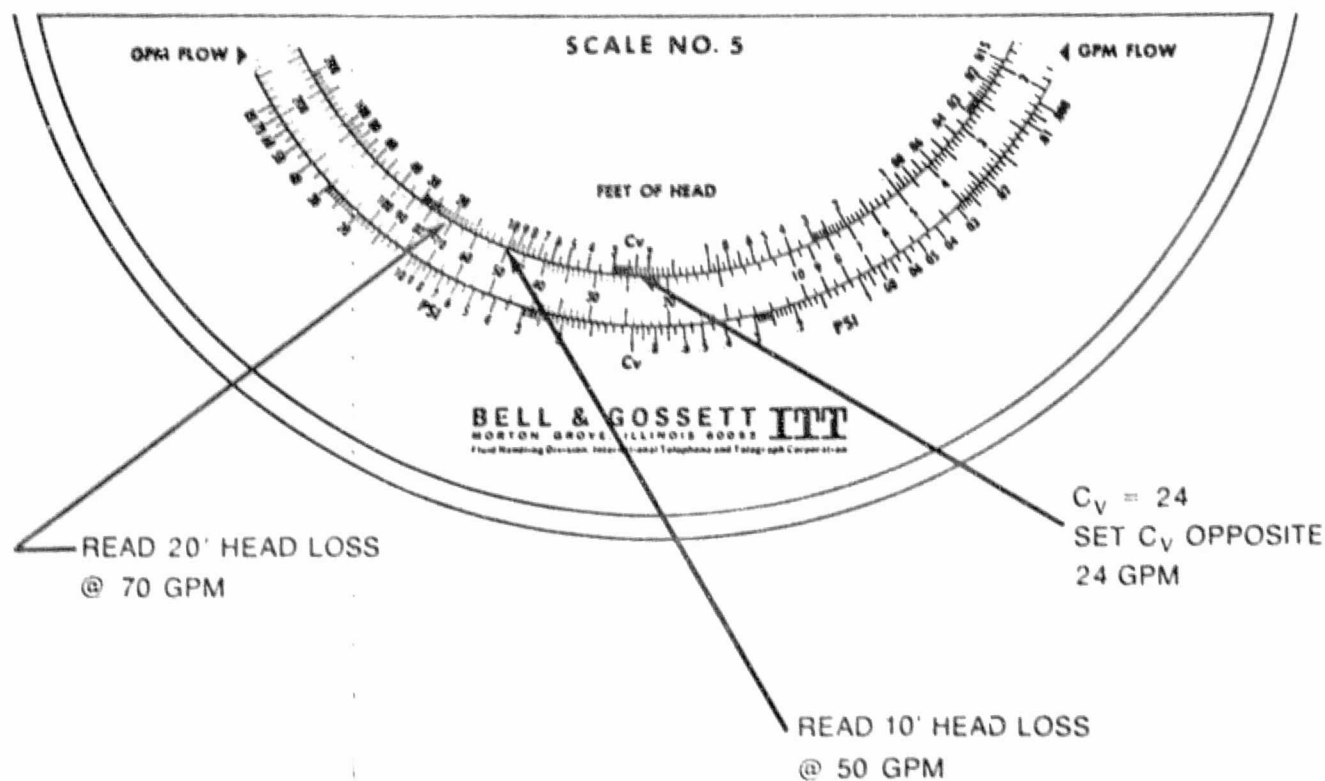


FIGURE 4

The plans will generally contain "scheduled" terminal equipment capacity, flow rate and head loss. The scheduled equipment may or may not be used, however, dependent on final bid selection. The terminal equipment schedule finally used must be based on the equipment actually "Bid Selected". The "Bid Selected" terminal equipment manufacturer should supply "certified" flow rate and head loss information for use by the balance contractor.

The terminal manufacturer may only be able to provide a single certified point for some terminal units; head loss for a single flow rate point. Given that required flow rate is different from that provided how can the new head loss be determined for the required flow?

Scale 5 of the B&G System Syzer can be used again. To illustrate, the terminal manufacturer states that a particular unit has 6' head loss at 4 GPM. Required flow rate is only 3 GPM. The procedure for establishing the head loss at 3 GPM is shown below as in Figure 5.

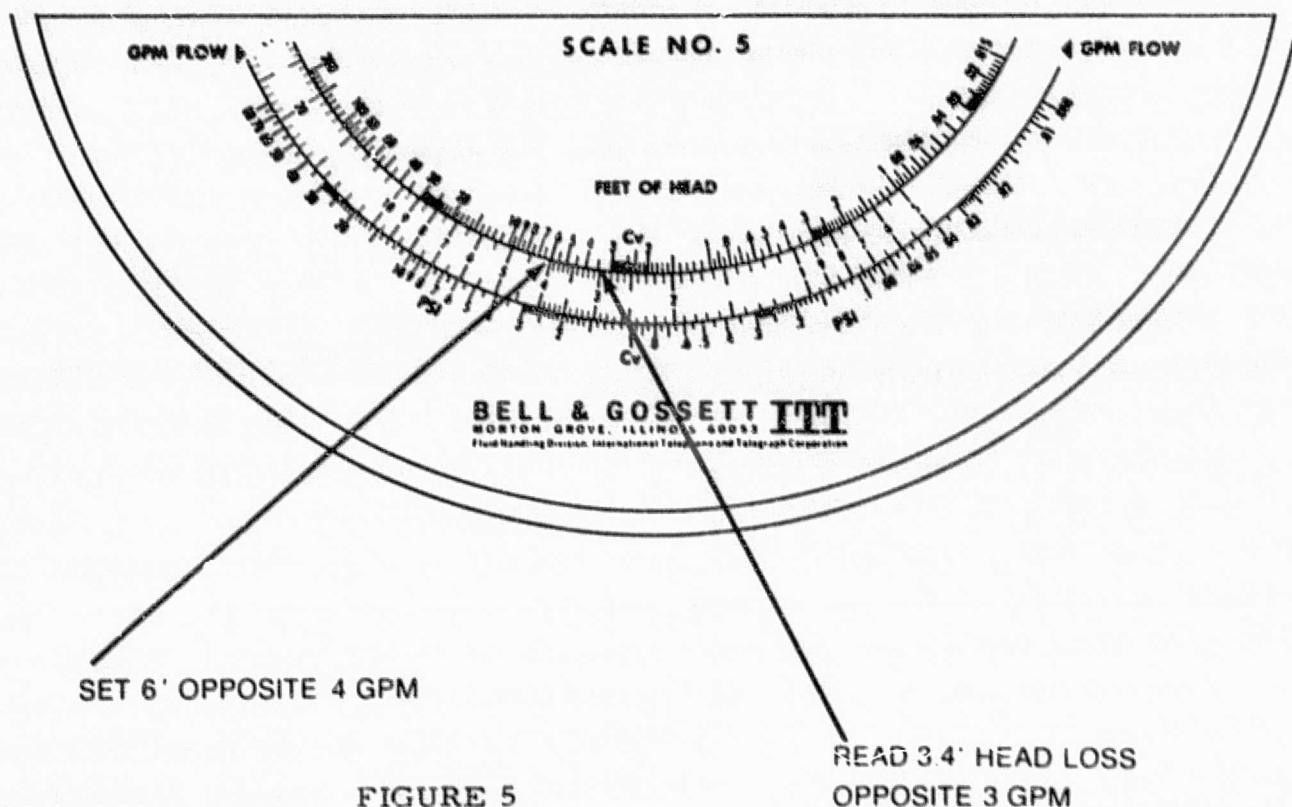


FIGURE 5

## EQUIPMENT ROOM HEAD LOSS

While equipment room head loss evaluation is not necessary for the proportional "pre-set" balance procedure, it is useful for evaluation of final pump head requirement and for prediction of estimated flow rates through each terminal (see page C-2).

Equipment room head loss determination is essentially the same as for the terminal sub-circuit in that it is composed of several parts:

1. Pipe and Fitting Head Loss
2. Control Valve Head Loss
3. Prime Equipment Head Loss (Boilers, Chillers, etc.)
4. Specialty Equipment Head Loss (Strainers, Air Separators, 3-D, Checks, etc.)

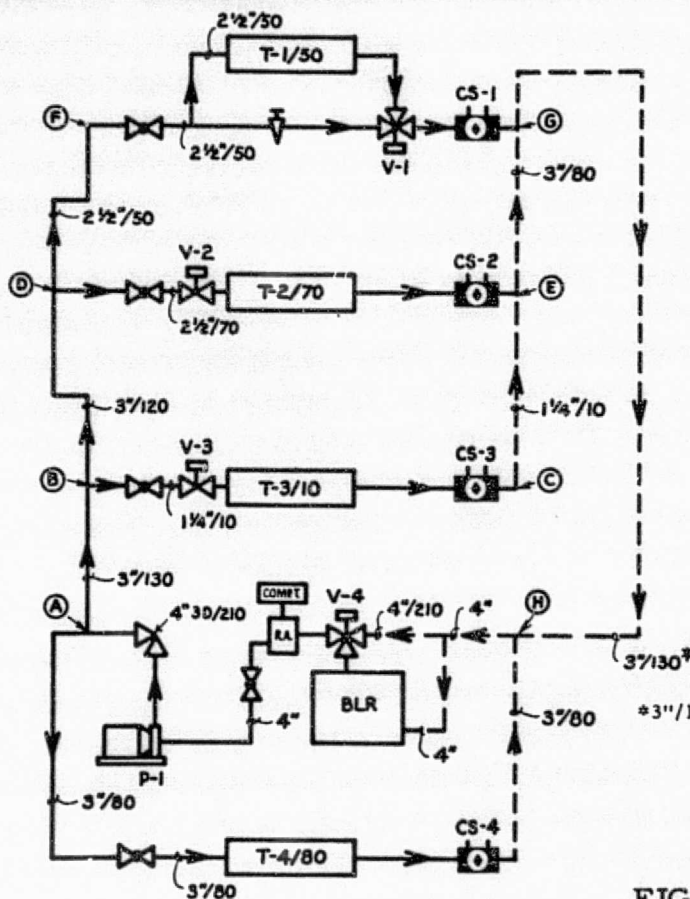
Pipe and fitting head loss procedures are the same as described for distribution piping head losses. Equivalent length for equipment room strainers, checks, etc. shown on the calculation chart.

Control valve head losses are the same as described on page C-10.

Head loss for boilers and chillers is available from the manufacturer.

Head loss for Bell & Gossett specialty equipment (Rolairtrol, 3-D and Suction Strainer refer to B&G Product Catalog).





**BID SELECTED**  
**TERMINAL UNIT SCHEDULE**

Terminal Unit	Mfg. No.	MBH	GPM	Ft. Hd.
T-1	--	---	50	5'
T-2	--	---	70	12'
T-3	--	---	10	3'
T-4	--	---	80	4'

**VALVE C<sub>v</sub> SCHEDULE**

Valve No.	C <sub>v</sub>	GPM
V <sub>1</sub>	24	50
V <sub>2</sub>	24	70
V <sub>3</sub>	4.8	10
V <sub>4</sub>	185	210

\*3"/130 Means:

3" Pipe @ 130 GPM  
For Pipe Section G-

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**FIGURE 6**

**EQUIPMENT ROOM PIPE SECTION REPRESENTED BY H-A (THRU BOILER)**

**Distribution Pipe Section Head Loss Tabulation Form**

Pipe Section	A-B	B-D	D-F	C-E	E-G	G-H	F-G	D-E	B-C	A-H	H-A
Flow Rate	130	120	50	10	80	130	50	70	10	80	210
Pipe Size	3"	3"	2 1/2"	1 1/4"	3"	3"	2 1/2"	2 1/2"	1 1/4"	3"	4" (min)
Measured Length	30'	40'	42'	50'	60'	132'	50'	50'	64'	110'	62'
Equivalent Length (Table 2)	El or Thru Tee	24'	18'	3 1/2'	8'	32'	18'	3 1/2'	32'	27 1/2'	27 1/2'
	Side Tee	16'					24'	24'	7'	16'	12'
	Valve						2'	2'	1'	2 1/2'	3'
	Other										
	Other										
Total Equivalent Length	46'	64'	60'	53 1/2'	68'	164'	94'	76'	75 1/2'	160 1/2'	104 1/2'
Pipe & Fitting Head Loss (Table 1)	1.9'	2.2'	1.2'	1.0'	1.1'	6.6'	1.9'	2.9'	1.4'	2.6'	2.8'
Terminal	Unit No.						T-1	T-2	T-3	T-4	—
	Head Loss						5'	12'	3'	4'	—
Control Valve	C <sub>v</sub>						24	24	4.8	—	185
	Head Loss						10'	20'	10'	—	3'
Total Head Loss with Control Valve							16.9'	34.9'	14.4'	6.6'	—
											3-D
											1.5'
											1.5'
											2'
											Total
											10.8'

**WORKSHEET 3**

## APPENDIX D

### SPARE PARTS LIST

The following is a list of spare parts recommended for the mechanical subsystem. These items are parts that would receive above average use or are subject to wear. The possibility of their failure during normal use is in our opinion greater than those parts not included. Since the system pumps are normally stocked shelf items, they have not been included. Failure of a major pump component would require a considerable period of down time for removal, repair and replacement on line. It is therefore left to the owners discretion whether to repair or replace the pump.

All parts listed below should be re-ordered upon their required use.

<u>ITEM</u>	<u>SIZE</u>	<u>QUANTITY</u>
Griswold Flow Control Device	3/4"	1
Griswold Flow Control Device	1 1/2"	1
Modumate Control Valve	3/4"	1
Modumate Control Valve	1"	1
Bell & Gossett Pump Mechanical Seal	-	1
Jenkins Ball Valve:		
Teflon Seal & O-Ring Packing	3/4"	1
Teflon Seal & O-Ring Packing	1"	1
Triac Board Form A	--	1
Sunkeeper Controller	--	1

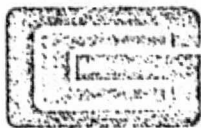
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APPENDIX E

EQUIPMENT INFORMATION



The Zone Control Valve Instruction Sheet V01184, Rev 3 and information bulletin A-412 have been deleted because they are copyrighted in 1972 and 1975 by International Telephone and Telegraph Corporation. For information contact Bell & Gossett, Fluid Handling Division - ITT, Morton Grove, Ill., 60053.



GRISWOLD  
CONTROLS

124 EAST DYER ROAD  
SANTA ANA, CALIF. 92707

SPECIFICATIONS  
FLOW CONTROL VALVE  
SHORT FORM.

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This specification has been prepared for the convenience of consulting engineers for specifying Griswold Flow Control Valves on jobs where a lengthy detailed description is not required.

- The Meter Kit (2.0) is an option which becomes a convenient tool for verifying terminal flows where a quantity of flow controls are involved.

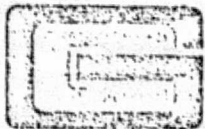
1.0 AUTOMATIC FLOW CONTROL VALVES

Flow control valves shall be factory calibrated, direct acting, automatic pressure compensating type. Each valve shall limit flow rates to within  $\pm 5$  accuracy, regardless of system pressure fluctuations. Valve control mechanism shall consist of a tamper proof, stainless steel cartridge assembly with open chambers and unobstructed flow passages. Cartridge assembly shall include a self-cleaning, spring-loaded moving cup guided at two separate points and shall utilize the full available differential pressure to actuate without hysteresis or binding. Four differential pressure ranges shall be available with the minimum range requiring less than 2 psid. Each valve to be provided with a metal tag, chain and stamped for system identification. Pressure taps and quick disconnect valves shall be provided with ferrous bodies. All hydronic system flow control valves shall be of one manufacturer. Flow control valves shall be manufactured by Griswold Controls, Santa Ana, California.

OPTIONAL ACCESSORY

2.0 FLOW MEASURING INSTRUMENT

- 2.1 Furnish portable flow measuring apparatus, complete with carrying case, pressure gauge, 3-way valve, hoses and connections. Unit to be compatible with automatic flow control valves to indicate pressure differential to determine flow rate through the valve.

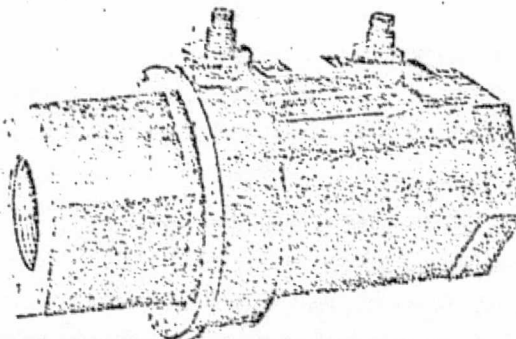
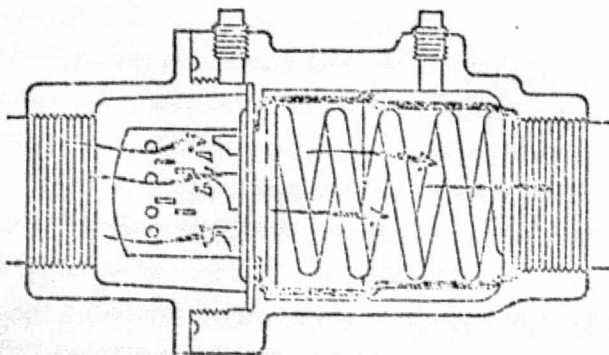


**GRISWOLD  
CONTROLS**

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## SUBMITTAL DATA GRISWOLD AUTOMATIC PRESSURE-COMPENSATING CONSTANT-FLOW CONTROL VALVES

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### The Griswold Constant-Flow Control Valve

The Griswold constant-flow control valve is a unique device. The control mechanism is totally enclosed within the fluid system and consists of just one moving part: a perforated, spring-loaded cup that moves in response to changes in the pressure drop (or differential) across the valve.

As the pressure drop increases (which would normally increase flow), the cup moves to close off a portion of the open orifices.

As the pressure drop decreases (which would normally decrease flow), the cup moves to expose additional orifice areas.

The result is constant flow through the valve, independent of the pressure drop across the valve (within the range defined below). The actual flow rate is set at the factory by the shape and size of the computer-designed orifice openings and the strength of the spring mechanism.

### Pressure-Drop Control Range

When the spring is fully expanded (at a low pressure-drop level) or fully compressed (at a high pressure-drop level), no further movement of the cup is possible. These two conditions therefore establish the effective pressure-drop range within which the valve can perform its constant-flow control function.

Beyond these upper and lower limits, the valve acts as a fixed-orifice device. With pressure drops below the minimum, the flow rate decreases. With pressure drops above the maximum, the flow rate increases. The actual flow rate under these extreme conditions can be determined by optional differential-pressure metering kits and conversion charts supplied by Griswold.

But in most applications, the valve is selected to operate within its constant-flow pressure-drop range.

### Factory-Set Flow Rates

Since the flow rate within the pressure-drop range is set at the factory, the required flow rate must be specified at the time that the valve is ordered.

To accommodate a wide variety of system requirements, Griswold valves are available with hundreds of different flow-rate settings,

ranging from 0.5 GPM to more than 12,000 GPM. Flow accuracy is within  $\pm 5\%$  over at least 95% of the pressure drop control range.

The charts on the following pages indicate the types and sizes of valves that are available. (Since in most cases the control mechanism is in the form of replaceable cartridges, flow rate can be adjusted in the field by simple cartridge replacement.)

### How to Select a Griswold Valve

Griswold constant-flow valves are available in four basic styles:

- a) Large size, flange mounted, in both gray and ductile iron.
- b) Medium size, with threaded ends, in gray iron.
- c) Medium and miniature sizes, with threaded or solvent weld ends, in PVC plastic.
- d) Miniature size, with threaded and sweat-type ends, in gray iron and wrought copper.

The first step in selecting a Griswold valve is to determine the most suitable style for the application.

With this accomplished, the specific valve is selected by following these four easy steps:

#### Step 1 Pressure-Drop Control Range

Determine the required pressure-drop range by calculating the maximum and minimum pressure drops that the valve will experience in operation. The maximum will typically occur when all other circuits in the system are closed. The minimum will occur when all other circuits are open. Choose the pressure-drop control range (see selection tables) that most closely matches these values.

#### Step 2 Size and Flow Rate in GPM

Within this range, select the valve size that will provide the required flow rate. Each valve size brackets a series of factory-set flow rates, determined by taking the lowest GPM for that size and adding the GPM increment shown. Calculate the GPM that will most closely approximate the required rate.

#### Step 3 Model Number

The size and control range will determine a Model Number. In the case of flange-mounted valves, there is a choice of two Model Numbers, depending on whether a gray or ductile iron housing is required.

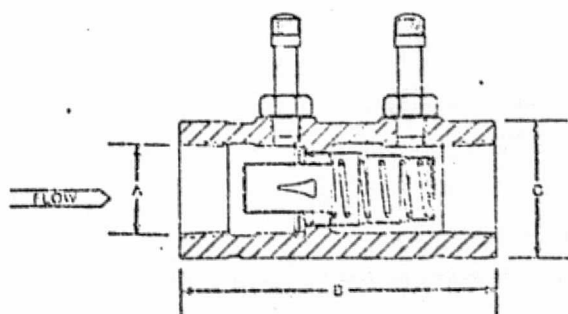
#### Step 4 Other Options

Make any other required decisions, such as pipe or tubing size, where there is a choice, and type of end fittings (e.g., threaded, solvent-weld, or sweat type).

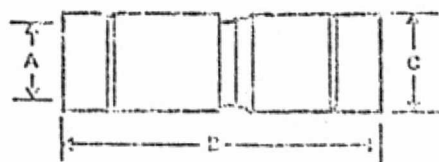
# MINIATURE VALVES, THREADED AND SWEAT-TYPE ENDS

PSI PRESSURE-DROP CONTROL RANGE	FACTORY—SET FLOW RATES				NOMINAL SIZE	MODEL NO. (THREADED)	MODEL NO. (SWEAT TYPE)
	MINIMUM	START	INCREMENTS	MAXIMUM			
1 to 14	.50 GPM 3.00 GPM	.66 GPM 3.33 GPM	.33 GPM .66 GPM	2.66 GPM 11.33 GPM	3/4" 1 1/4" - 1 1/2"	3521 3531	3551 3561
2 to 32	.75 GPM 4.5 GPM	1.00 GPM 5.0 GPM	.5 GPM 1.0 GPM	4.0 GPM 17.0 GPM	3/4" 1 1/4" - 1 1/2"	3522 3532	3552 3562
4 to 57	1.00 GPM 6.00 GPM	1.33 GPM 6.66 GPM	.66 GPM 1.33 GPM	5.33 GPM 22.66 GPM	3/4" 1 1/4" - 1 1/2"	3524 3534	3554 3564
8 to 128	1.50 GPM 9.0 GPM	2.0 GPM 10.0 GPM	1.0 GPM 2.0 GPM	8.0 GPM 34.0 GPM	3/4" 1 1/4" - 1 1/2"	3528 3538	3558 3568

## THREADED TYPE ENDS



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SWEAT-TYPE ENDS



## DIMENSIONS (INCHES)

SIZE	A (NPT)	B MAXIMUM	C* MAXIMUM
3/4"	3/4 - 14	3.5	1.75
1-1/2"	1-1/2 - 11-1/2	6.0	2.9

\* Add 1-1/2" for Schrader valve kit

## SPECIFICATIONS

Pressure/Temperature Rating	250 PSI/400°F
Internal Parts	AISI Type 300 series passivated stainless steel, with AISI 17-7 PH spring.
Body Material	Gray Iron ASTM A126-G1T Class 30

## DIMENSIONS (INCHES)

SIZE	A (I.D.)	B MAXIMUM	C MAXIMUM
3/4"	0.875/0.880 (1)	4.00	0.982
1-1/2"	1.625/1.6315 (2)	6.50	1.762

- (1) Will accept 7/8" O.D. tube or 3/4" type K, L & M copper tube  
(2) Will accept 1-5/8" O.D. tube or 1-1/2" type K, L & M copper tube

## SPECIFICATIONS

Pressure/Temperature Rating	250 PSI/400°F
Internal Parts	AISI type 300 series passivated stainless steel, with AISI 17-7 PH spring.
Body Material	Wrought iron or ASTM A275-62, Type 122

## INSTALLATION INSTRUCTIONS

- No special installation techniques are required. Install flow directional arrow in direction of flow.
- Clean lines up stream of valve of particles larger than approximately 1/16" diameter (equivalent to 20 mesh strainer).
- Seal threaded-end valves with approved pipe compound (dope). Torque on small valves should not exceed 75 ft. lbs.
- Assemble flange-mounted valves with studs provided by Griswold and flanges and gaskets furnished by installer.

## MAINTENANCE INSTRUCTIONS

- Griswold valves are factory assembled and tested. They are tamper proof, non-field adjustable. Specified flows are certified within ±5%.
- Those valves furnished with pressure fittings may be checked with suitable gauge. If found to be operating out of specified range, refer to conversion tables to determine flow.

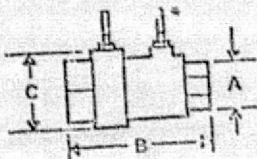


# GRAY IRON VALVES, THREADED ENDS

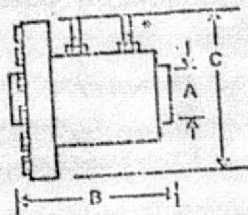
PRESSURE-DROP CONTROL RANGE PSI	FACTORY—SET FLOW RATES			NOMINAL SIZE	MODEL NO.
	MINIMUM	INCREMENTS	MAXIMUM		
1.3 to 20	14	2 GPM	60 GPM	1½" & 2"	3281
	62	2 GPM	180 GPM	3"	3331
2 to 32	17.5	2.5 GPM	75 GPM	1½" & 2"	3282
	77.5	2.5 GPM	225 GPM	3"	3332
4 to 57	23.33	3.33 GPM	100 GPM	1½" & 2"	3284
	103.33	3.33 GPM	300 GPM	3"	3334
8 to 128	35	5 GPM	150 GPM	1½" & 2"	3288
	155	5 GPM	450 GPM	3"	3338

\* Add 3" for Schrader valve kit

1-1/2" & 2"



3"



## DIMENSIONS (INCHES)

A (NPT)	B MAXIMUM	C* NOMINAL
1-1/2"	8-5/8	4.81
2"	8-5/8	4.81
3"	9-3/8	10.00

## SPECIFICATIONS

Pressure/Temperature Rating  
Internal Parts  
Body  
Body Tappings

200 PSI/250°F.

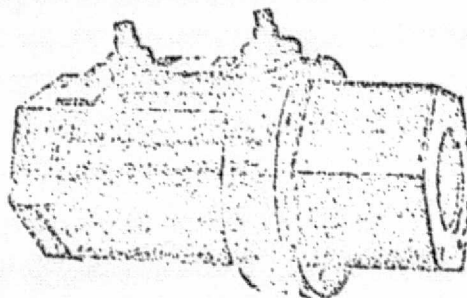
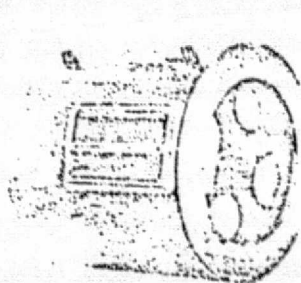
Phenolic spacers; AISI Type 300 series passivated stainless steel, with AISI 17-7 PH spring.

Gray-iron ASTM A126-61T Class 30  
1/4 NPT

## HOW TO ORDER GRISWOLD CONSTANT-FLOW CONTROL VALVES

To assure delivery of the specific valve required, the following information should be supplied:

1. Model Number
2. Flow Rate (To Nearest GPM Flow Increment).\*
3. Size and Type of End Fitting.\*
4. Accessories (See Accessory Price List).
5. Temperature of Fluid.
6. Fluid, if other than water. Specify:
  - a) Viscosity
  - b) Specific Gravity



# SOLDER END BRONZE GATE

FIG. 1240,  $\frac{3}{8}$ "-3"

FIG. 1241, with Drain Plug,  $\frac{1}{2}$ "-2"

200 lbs. Non-Shock Cold Water  
For Types K, L and M Copper Tubing

Solid Wedge  
Inside Screw  
Non-Rising Stem  
Screw-In Bonnet



FIG. 1241

FIG. 1240

## MATERIALS LIST

PART	SPECIFICATION
1 HANDWHEEL LOCK NUT	Cadmium Plated Steel
2 IDENTIFICATION PLATE	Aluminum
3 PERFECT-GRIP WHEEL	Malleable Iron
4 STEM	ASTM D584, Alloy 876, Silicon Brass
5 PACKING NUT	ASTM B62, Bronze
6 GLAND	ASTM B16, Brass Rod
7 PACKING	TFE Impregnated Asbestos
8 PACKING BOX	ASTM B62, Bronze
9 BONNET	ASTM B62, Bronze
10 SOLID WEDGE	ASTM B62, Bronze
11 BODY	ASTM B62, Bronze
12 DRAIN PLUG NIPPLE	On Fig. 1241 only, Brass Rod
13 DRAIN PLUG CAP	On Fig. 1241 only, Brass Rod
14 DRAIN PLUG WASHER	On Fig. 1241 only, Rubber

## DIMENSIONS - INCHES

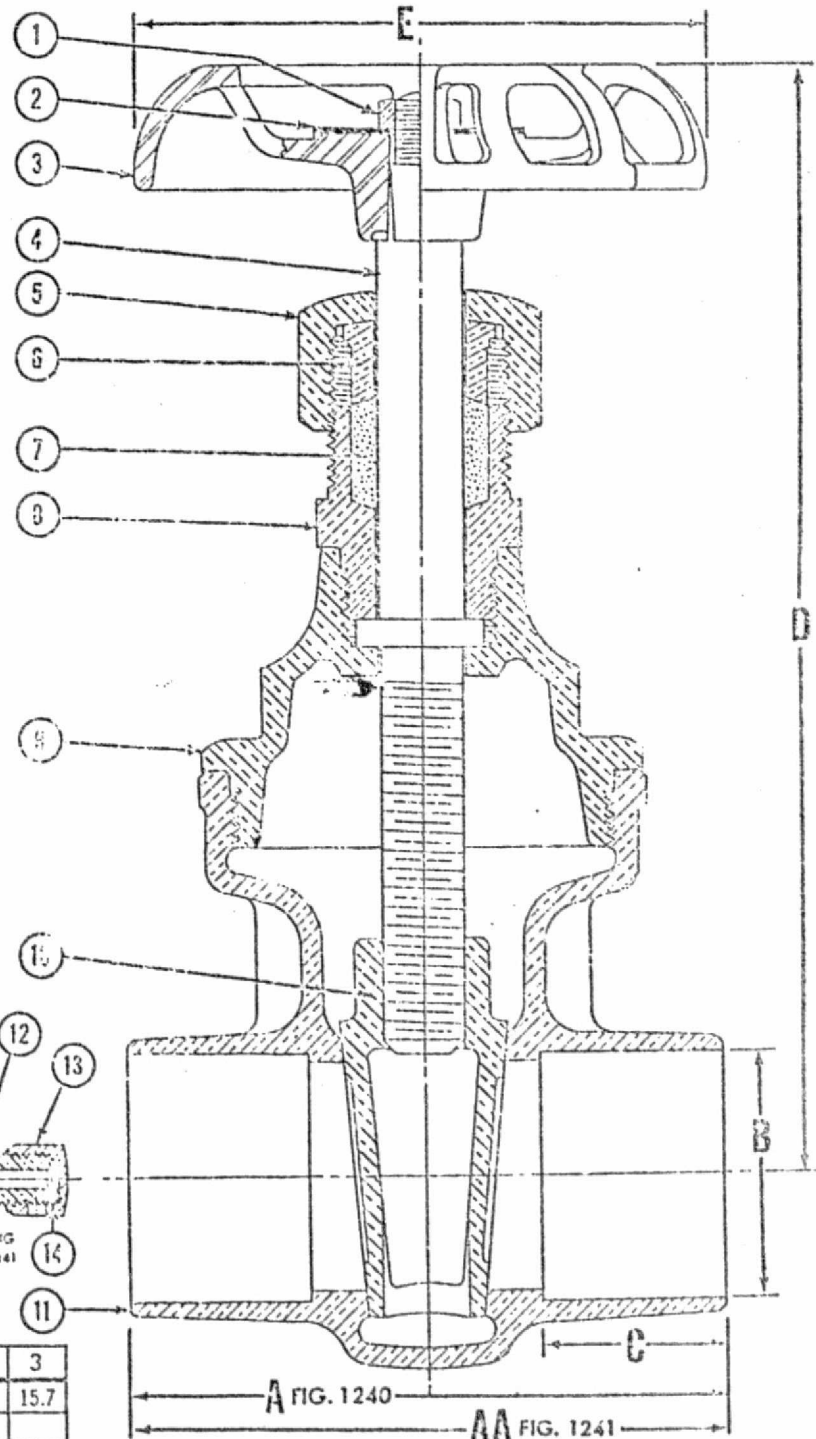
SIZE	A	AA	B	C	D	E
$\frac{3}{8}$	1 $\frac{1}{4}$		.503	$\frac{1}{2}$	$\frac{3}{4}$	1 $\frac{1}{2}$
$\frac{1}{2}$	2	2 $\frac{3}{8}$	.626	$\frac{1}{2}$	4 $\frac{1}{2}$	2 $\frac{1}{4}$
$\frac{3}{4}$	2 $\frac{1}{2}$	2 $\frac{1}{2}$	.876	$\frac{5}{8}$	4 $\frac{1}{2}$	2 $\frac{1}{4}$
1	3	3 $\frac{1}{2}$	1.129	$\frac{1}{2}$	6	3
1 $\frac{1}{4}$	3 $\frac{1}{2}$	3 $\frac{1}{2}$	1.379	1	6 $\frac{3}{8}$	3 $\frac{1}{4}$
1 $\frac{1}{2}$	3 $\frac{1}{2}$	4 $\frac{1}{2}$	1.629	1 $\frac{1}{8}$	7 $\frac{1}{8}$	3 $\frac{1}{4}$
2	4 $\frac{1}{2}$	4 $\frac{1}{2}$	2.129	1 $\frac{1}{2}$	8 $\frac{1}{4}$	4 $\frac{1}{2}$
2 $\frac{1}{2}$	4 $\frac{1}{2}$		2.629	1 $\frac{1}{2}$	9 $\frac{1}{4}$	4 $\frac{1}{2}$
3	5 $\frac{1}{2}$		3.129	1 $\frac{1}{2}$	11 $\frac{1}{4}$	5 $\frac{1}{4}$

## WEIGHTS-POUNDS

SIZE	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	1 $\frac{1}{4}$	1 $\frac{1}{2}$	2	2 $\frac{1}{2}$	3
Fig. 1240	.7	1.0	1.5	2.4	3.3	4.6	7.1	10.5	15.7
Fig. 1241		1.1	1.6	2.5	3.5	4.8	7.3		

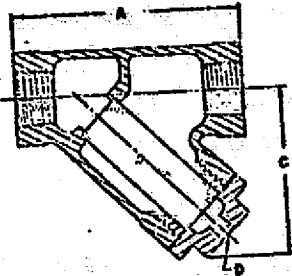
Safe pressure-temperature rating of solder-joint system depends not only on valve, fitting and tubing strength, but also on composition of solder used for joints.

Pressure-temperature ratings for solder joints made with typical commercial solders can be found in Table A of ANSI B16.18-1972 and Table I of MSS SP-73-1970.



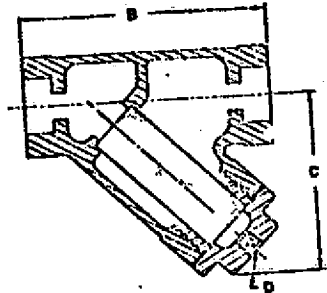
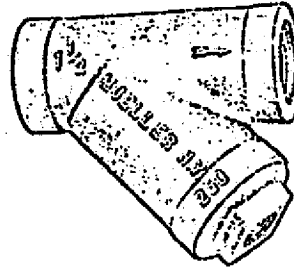
#351-1/2

#250 SWP SCREWED END



#352-1/2

SOLDER JOINT OR SILVER BRAZING  
(WITH OR WITHOUT PRE-INSERTED  
SILVER SOLDER RINGS)



COMMERCIAL AND/OR MILITARY SPECIFICATION

IMPORTANT: IN THE CASE OF #352-1/2 SOLDER JOINT STRAINERS  
SPECIFY THEIR END USE, COPPER TUBING OR PIPE

WORKING PRESSURE: 250 SWP @ 425°F.

**SERVICE RECOMMENDATIONS:** These strainers offer complete protection to pumps, meters, traps, valves and similar expensive automatic equipment. Installation of a strainer before any automatic equipment will insure trouble free service and avoid the costly repairs or replacement so often caused by the introduction of foreign matter in pipe lines.

**FEATURES:** In addition to all of the usual commercial applications these strainers are in complete accordance with Military specifications. #351-1/2 screwed end conform with MIL-S-2953, Class A and #352-1/2 strainers with BuShip dwg. #5000-S4823-841499.

**CONSTRUCTION:** All sizes, in both types feature a machined seat in the body, which, combined with the machined seat in the cap assures perfect screen alignment and easy dis-assembly. All sizes assembled with copper gaskets. Valve bronze used exclusively for both types.

**BLOWOFFS:** For commercial use both types are furnished with FIPT blowoff connections, unplugged. In accordance with the applicable Military specs MIL-S-2953 strainers are furnished with a blind cap and #5000-S4823-841499 strainers with plugged blowoff connections. See chart below for blowoff sizes.

**SCREENS:** Perforated brass screens normally furnished for commercial applications and perforated Monel (nickel-copper alloy) for Government specifications. All other perforations, metals and mesh available — see page 6.

**STEAM SERVICE:** 3/4" Perforations.  
**WATER SERVICE:** 1/2" Perforations.

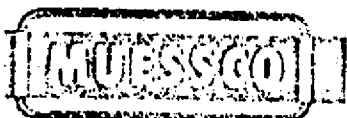
**PRESSURE DROP:** See page 7.

DIMENSIONS AND WEIGHTS — APPROXIMATE

SIZE	1/4"	3/8"	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"
"A"	2 1/2"	2 1/2"	3 1/4"	3 3/4"	4 1/2"	5 1/4"	5 3/4"	7 1/4"	8 1/4"	11 3/4"
"B"	2 1/4"	2 1/4"	2 1/4"	3 1/4"	4 1/4"	4 1/4"	5 1/4"	6 1/4"	7 1/4"	11 1/4"
"C"	1 1/2"	1 1/2"	2 1/2"	2 1/2"	3	3 1/4"	4 1/4"	5 1/4"	6 1/4"	7 1/2"
"D"	1 1/2"	1 1/2"	2 1/2"	2 1/2"	3	3 1/4"	4 1/4"	5 1/4"	6 1/4"	7 1/2"
WEIGHT	1	1	1	1 1/2	2 1/2	4 1/2	6	10 1/2	15 1/2	35

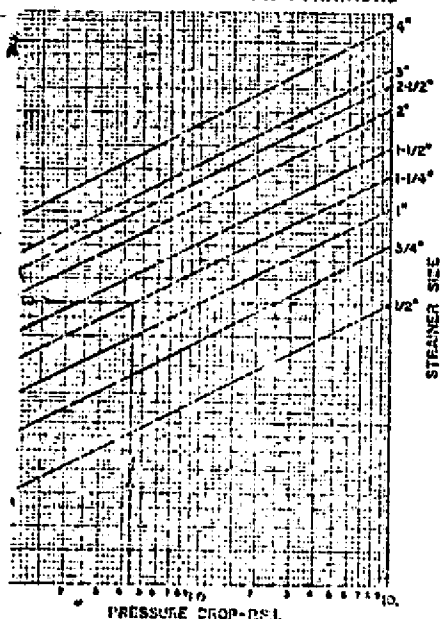
Page E-8

MUELLER STEAM SPECIALTY BROOKLYN, N.Y.



# STRAINER PRESSURE DROP CHARTS

SCREWED END "Y" TYPE STRAINERS



Example: To determine pressure drop through 1-1/4" strainer at 50 g.p.m. enter chart at left (50 g.p.m.) read horizontally to strainer size (1-1/4") read vertically downward for answer (.40 pounds).

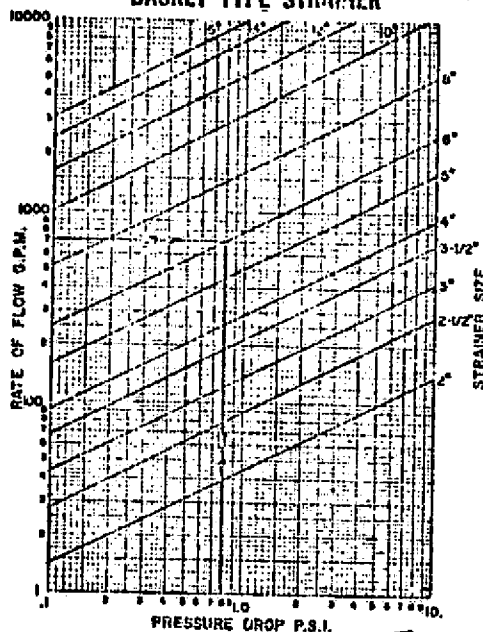
**MULTIPLYING FACTOR:** All results are based on the use of .045 diam. through 7/16" am. perforations. Correction factor for use of smaller perforations available on request.

ash lined perforated metal screens: multiply pressure loss by 1.25.

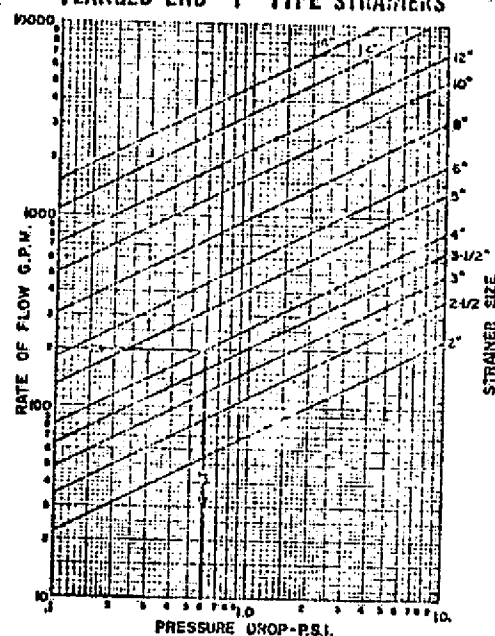
**CLOGGED SCREENS:** These charts represent results of tests conducted with strainers containing clean screens. With screens % clogged pressure drop results are approximately double those shown in charts.

**MUELLER STEAM SPECIALTY**  
30 MESEROLE AVE.  
BROOKLYN, N.Y. 11222

BASKET TYPE STRAINER



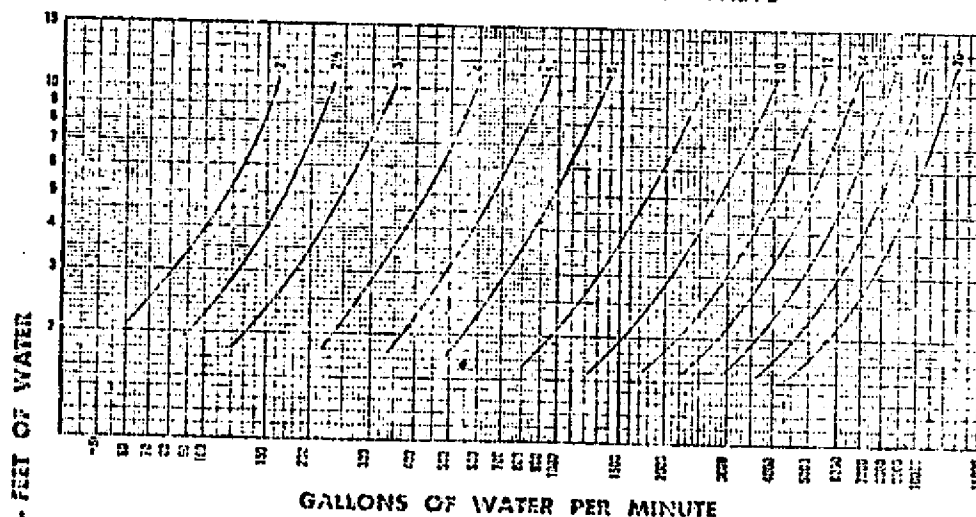
FLANGED END "Y" TYPE STRAINERS



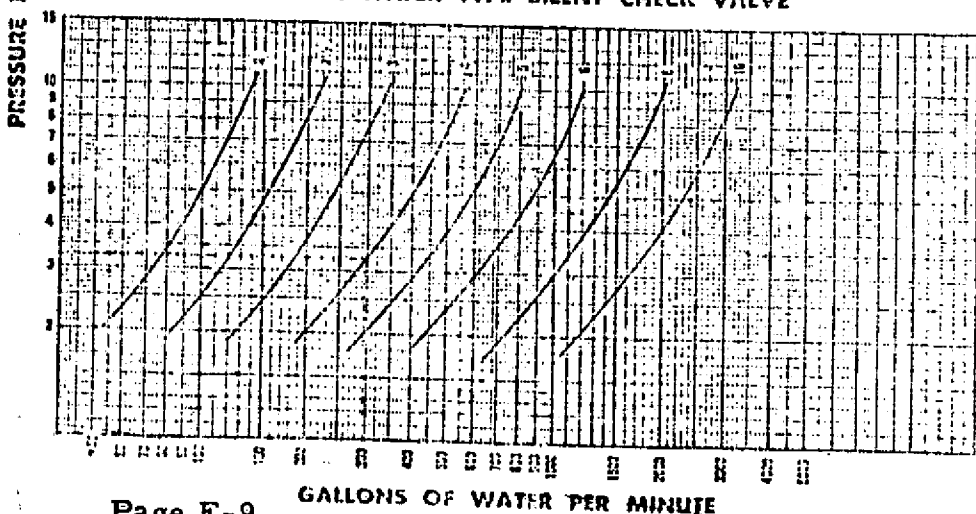
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## SILENT CHECK VALVE PRESSURE DROP CHARTS

PRESSURE DROP — FEET OF WATER  
MUELLER GLOBE TYPE SILENT CHECK VALVE



PRESSURE DROP — FEET OF WATER  
MUELLER WAFFER TYPE SILENT CHECK VALVE





# BRONZE SWING CHECK

FIG. 1222, 3/8"-3"

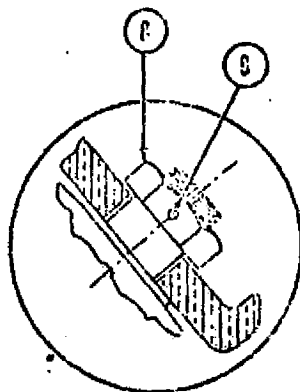
300 lbs. Non-Shock Cold Water  
for Types K, L and M Copper Tubing  
Regrinding Bronze Disc



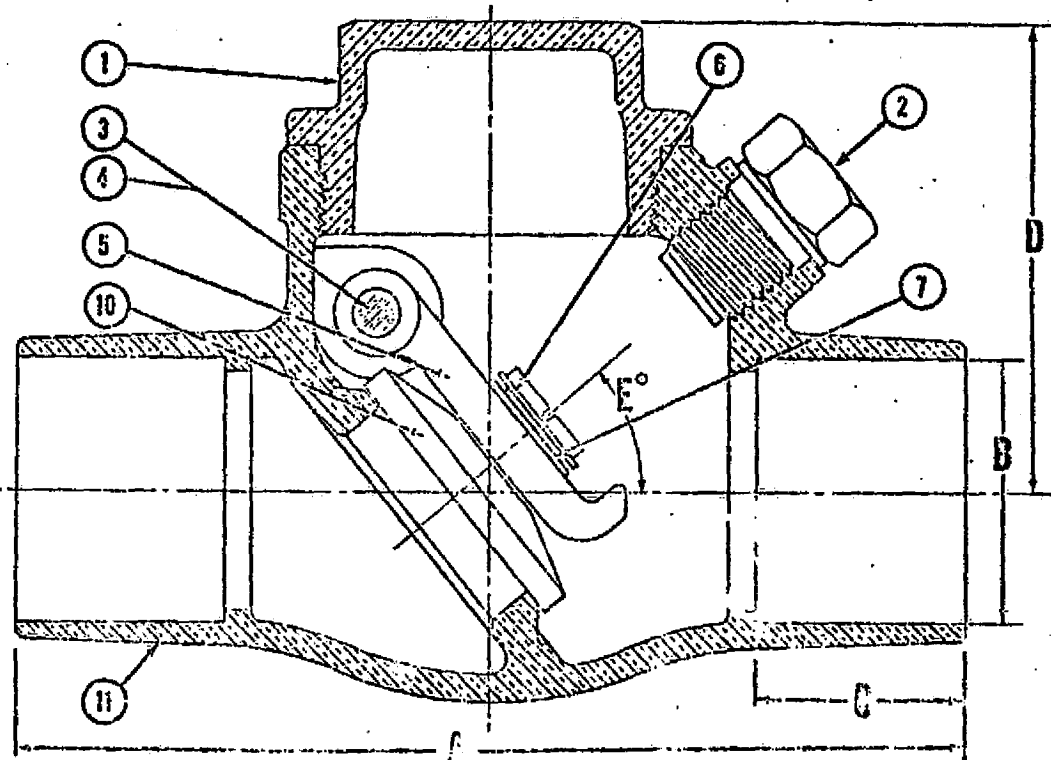
FIG. 1222

Safe pressure-temperature rating of solder-joint system depends not only on valve, fitting and tubing strength, but also on composition of solder used for joints.

Pressure-temperature ratings for solder joints made with typical commercial solders can be found in Table A of ANSI B16.18-1972 and Table I of MSS SP-73-1970.



HANGER ASSEMBLY  
2 1/2" and 3" valves



## MATERIALS LIST

PART	SPECIFICATION
1 CAP	ASTM B62, Bronze
2 STOP PLUG	ASTM B16, Brass Rod
3 SIDE PLUGS	ASTM B16, Brass Rod
4 HANGER PIN	ASTM B16, Brass Rod
5 HANGER	ASTM B61, Bronze
6 RETAINING RING	3/8"-2" only, Beryllium Copper
7 WASHER	1"-2" only, ASTM B21, Alloy 464 Brass
8 HANGER NUT	2 1/2", ASTM B16, Phosphor Bronze Rod 3", ASTM B61, Bronze
9 HANGER NUT PIN	2 1/2" and 3", Bronze Cutter Pin
10 DISC	3/8"-3/4", ASTM B140, Alloy 314, Bronze Rod 1"-3", ASTM B61, Bronze
11 BODY	ASTM B62, Bronze

## DIMENSIONS - INCHES

SIZE	A	B	C	D	E
3/8	2 1/4	.503	9/32	1 1/8	40°
1/2	2 1/2	.628	11/32	1 1/8	40°
3/4	3 1/8	.878	15/32	1 7/16	40°
1	4 1/8	1.129	1 1/16	2 1/16	40°
1 1/4	4 7/8	1.379	1	2 3/8	40°
1 1/2	5 1/2	1.629	1 1/8	2 7/16	40°
2	6 1/8	2.129	1 3/4	3 1/16	40°
2 1/2	7 3/8	2.629	1 1/2	3 11/16	40°
3	8 3/8	3.129	1 11/16	4 1/2	40°

## WEIGHTS-POUNDS

SIZE	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3
Fig. 1222	.5	.6	1.1	1.7	2.6	3.6	6.6	9.5	14.1

# COMPACT PATTERN

## FORGED BRONZE BALL VALVE

FIGS. 1100-R, 1100-T, Solder Ends, 1/2"-1"

FIGS. 1100-RE, 1100-TE Solder Ends, 1/2"-3/4"

400 lbs. Non-Shock Cold Water, Oil, Gas

Fig. 1100-R, Buna N Seats

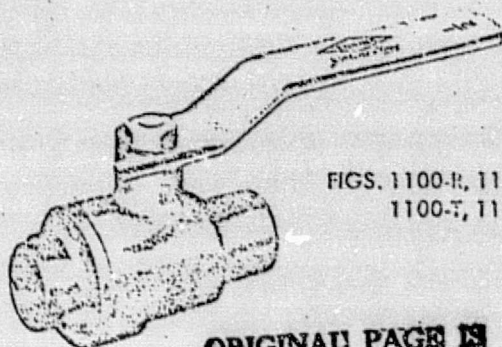
Fig. 1100-RE, Buna N Seats, Balancing Stop Plate

Fig. 1100-T, Teflon Seats

Fig. 1100-TE, Teflon Seats, Balancing Stop Plate

Safe pressure-temperature rating of solder-joint system depends not only on valve, fitting and tubing strength, but also on composition of solder used for joints.

Pressure-temperature ratings for solder joints made with typical commercial solders can be found in Table A of ANSI B16.18-1972 and Table I of MSS SP-73-1970.

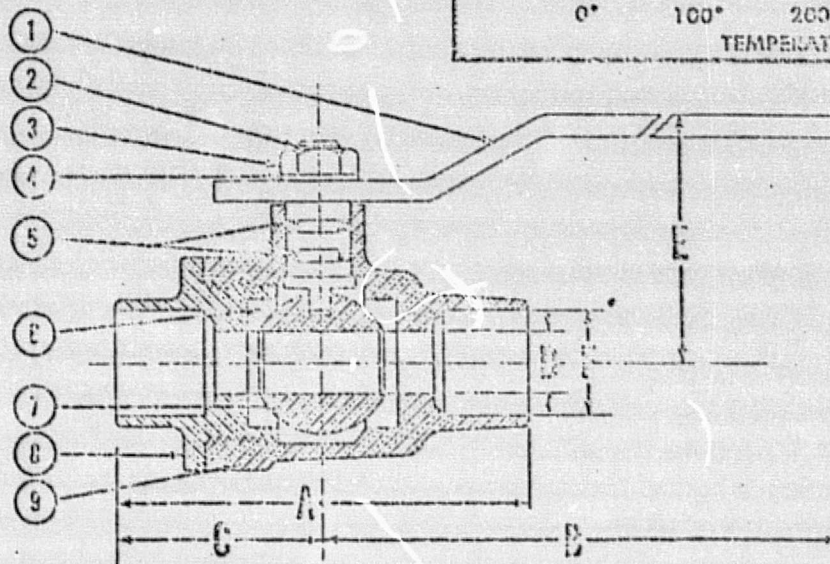
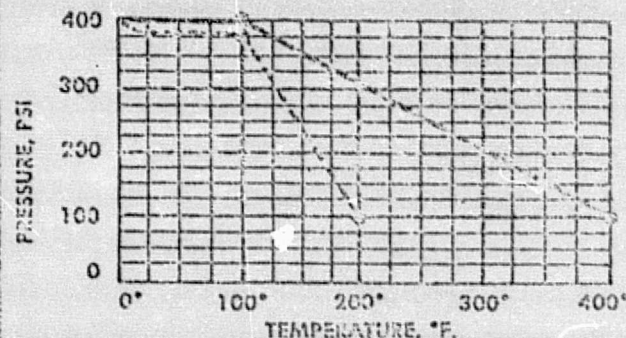


FIGS. 1100-R, 1100-RE  
1100-T, 1100-TE

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### VALVE SEAT PRESSURE - TEMPERATURE RATINGS

TEFLON (—) 400 psi, 100° F.  
100 psi, 400° F. BUNA N (---) 400 psi, 100° F.  
100 psi, 200° F.



### MATERIALS LIST

PART	SPECIFICATION
1 HANDLE	Rustproofed Steel
2 STEM	ASTM B-21 Alloy 485, Bronze
3 HANDLE NUT	Cadmium Plated Steel
4 LOCKWASHER	Cadmium Plated Steel
5 O-RING PACKING	Figs. 1100-R, -RE, Buna N Figs. 1100-T, -TE, Viton A(top) Teflon (bottom)
6 SEAT	Fig. 1100-R, Buna N Fig. 1100-T, Teflon
7 BALL	ASTM B-21 Alloy 485, Bronze
8 CAP	ASTM B-283 Alloy 485, Bronze
9 BODY	ASTM B-283 Alloy 485, Bronze

### DIMENSIONS-INCHES

SIZE	A	B	C	D	E	F
1/2	2 3/8	3 3/4	1 3/4	3/4	1 1/4	.530 .628
3/4	2 1/2	3 3/4	1 1/2	1/2	1 1/2	.880 .878
1	3 3/8	3 3/4	1 1/2	3/4	1 1/4	1.131 1.129

### WEIGHT-POUNDS

SIZE	1/2	3/4	1
Each	.5	1.0	1.3

# Marsh Standard Gauges

Accurate to  $\pm 2\%$  full scale

## Specifications

### Accuracy

Grade B Pressure and Vacuum Gauge specifications as established by U.S.A. Standard B40.1—1968.  
Accuracy  $\pm 2\%$  of the total dial range.

### Sizes and connections

1½", 2", 2½", 3½" and 4½" dial sizes. All connections are male N.P.T. 1½" size has ½" bottom or center back outlet. 2" and 2½" sizes have ½" or ¾" bottom or center back outlets. 3½" size has ½" bottom or center back outlet. 4½" size has ¾" bottom outlet.

### Bourdon tube assembly

*For Vacuum and Pressures to 600 psi*  
Tube, tip and socket are copper alloy.  
Assembly is soldered.

*For High Pressures, 1,000 to 5,000 psi*  
Ni-Span-C Bourdon tube; copper alloy tip and socket. Assembly is brazed above 3,000 psi.

### Movement

Standard movement is copper alloy construction. Plates and sector are hard brass stampings. Gear teeth of sector and pinion are precision machined to give smooth pointer motion. A quality bronze hairspring is matched by torque to the pressure range of the instrument. Available with either plain or bushed Recalibrator movements. (See selection charts.)

### Dial

Dials are made of steel, with white litho background and black printed matter.

### Case patterns and construction

Plain Case, Slip Ring—drawn steel, 1½", 2", 2½", 3½", 4½".

Plain Clearfront—drawn steel, 1½".

Stainless Clearfront—drawn stainless steel, 2".

Flush Case, Snap Ring—drawn steel, 2", 2½", 3½".

Oil-Filled Plain Case, Nonremovable Ring—phenolic, 2½".

Brass Case, Screwed Ring (Compressed Gas)—drawn brass, 2", 2½".

Drawn steel cases and rings are finished in black semi-gloss enamel.

Drawn stainless steel cases have a brushed stainless steel finish.

Drawn brass cases have a polished brass finish.

### Phenolic Case Oil-Filled Gauges—special construction features

Neoprene plug acts as a safety valve, venting pressure buildup to prevent blowout.

Snap-in, nonremovable polypropylene retaining ring.

Accuracy is  $\pm 3\%$  full scale.

300 series stainless steel internal construction is available in bottom connection in selected ranges.

2½" dial size only.

Cupped aluminum dial with black numerals on white background.

Restrictor screw is supplied as standard.

Glycerin filling dampens pulsation and

vibration. Suitable for use from  $-30^{\circ}$  to  $150^{\circ}\text{F}$ . Other fills available on special order.

### Brass Gauge—special construction features

Knurled screwed ring.

Beveled glass lens.

"USE NO OIL" dial for all ranges.

Cubic feet of gas as well as pressure indicated on ranges of 1,000 psi and above.

Recessed safety blowout back on high-pressure models.

U.L. approved for oxygen service on high-pressure ranges of 1,000 psi and above.

### Lens

All Standard Gauges are supplied with glass lens except for Clearfront cases, which have a molded acrylic press-fit front.

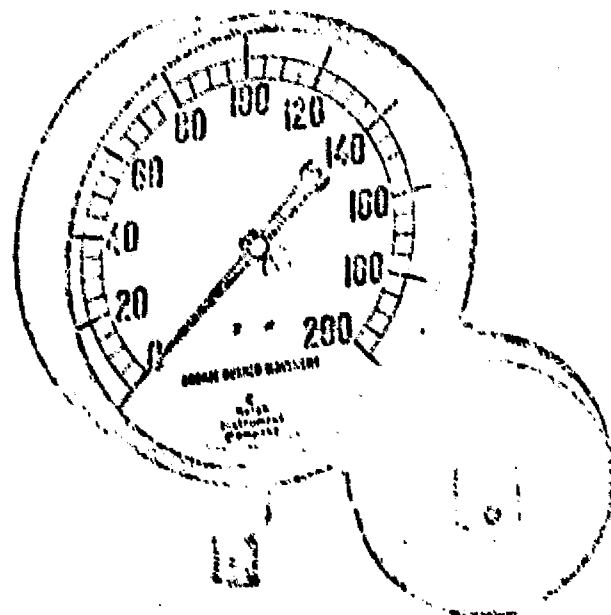
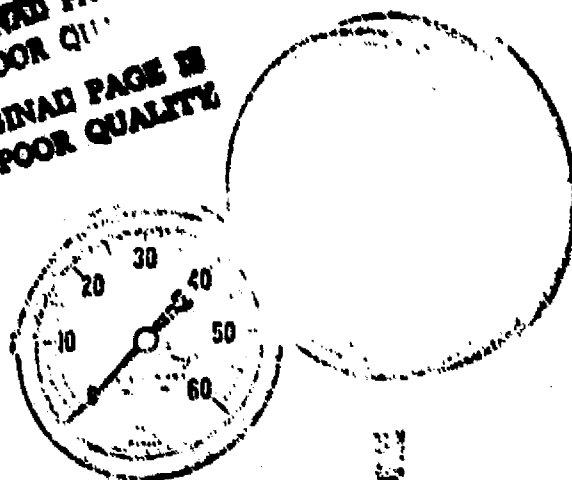
# Marsh Standard Gauge Selection Guide (continued)

DIAL SIZE		2 1/2"								
CASE PATTERN		Plain								
CONNECTION LOCATION		Bottom					Center Back			
CONNECTION SIZE		1/8"			1/4"			1/8"	1/4"	
MOVEMENT TYPE		Plain		Recalibra- tor Plain	Plain	Recalibra- tor Bushed	Plain	Plain	Recalibra- tor Bushed	
RESTRICTOR		None	Yes	Yes	None	None	None	None	Yes	
COPPER ALLOY BURDON TUBE	VACUUM	30" Hg. Vacuum	J4005	*	J4305	J4605	J4805	J5005	J5405	J5705
	COMPOUND	30" Hg. x 30 psig	*	J4112	J4312	J4612	J4812	*	J5412	J5712
		30" Hg. x 60 psig	*	J4114	J4314	J4614	J4814	*	J5414	J5714
		30" Hg. x 100 psig	*	J4116	J4316	J4616	J4816	*	J5416	J5716
		30" Hg. x 150 psig	*	J4118	J4318	J4618	J4818	*	J5418	J5718
		30" Hg. x 200 psig	*	J4120	J4320	*	*	*	J5420	J5720
		30" Hg. x 300 psig	*	J4124	J4324	J4624	J4824	*	J5424	J5724
		30" Hg. x 400 psig	*	J4126	J4326	*	*	*	J5426	J5726
	PRESSURE	0 to 30 psig	*	J4142	*	J4642	J4842	J5042	J5442	*
		0 to 50 psig	*	*	*	*	*	*	*	*
		0 to 60 psig	*	J4146	*	J4646	J4846	J5046	J5446	*
		0 to 100 psig	*	J4148	*	J4648	J4848	J5048	J5448	*
		0 to 160 psig	*	J4152	*	J4652	J4852	J5052	J5452	*
		0 to 200 psig	*	J4154	*	J4654	J4854	J5054	J5454	*
		0 to 300 psig	*	J4156	J4358	J4658	J4858	J5058	J5458	*
		0 to 400 psig	*	J4160	J4360	J4660	J4860	J5060	J5460	*
		0 to 500 psig	*	J4162	J4362	*	*	*	*	*
		0 to 600 psig	*	*	*	J4664	J4864	J5064	J5464	*
	HIGH PRESSURE	0 to 1,000 psig	*	*	*	*	J4872 <sup>1</sup>	*	*	J5772
		0 to 1,500 psig	*	*	*	*	J4874 <sup>1</sup>	*	*	*
		0 to 2,000 psig	*	*	*	*	J4876 <sup>1</sup>	*	*	J5776
		0 to 3,000 psig	*	*	*	*	J4878 <sup>1</sup>	*	*	J5778
		0 to 4,000 psig	*	*	*	*	*	*	*	*
		0 to 5,000 psig	*	*	*	*	J4882 <sup>1</sup>	*	*	*

Though this exact gauge is not available as a stock item, your needs may be filled immediately by a very similar stock gauge listed nearby. If, however, no stock gauge can be found to fill your quantity needs, contact Marsh.

Gage selection of stock items subject to change without notice.

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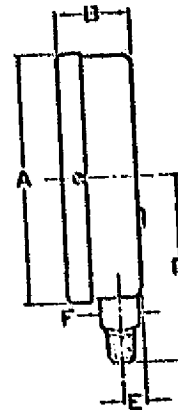
# Dial Ranges

# Case Patterns

## PLAIN CASE

Drawn steel construction

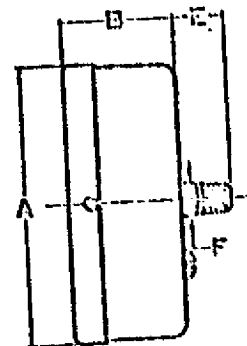
Bottom connection—1½", 2", 2½", 3½", 4½".



Size	A	B	D (½ conn.)	D (¼ conn.)	E	F
1½	1½/₄	1½/₈	1½/₈	1½/₈	½	7/₁₆ Sq.
2	2½/₈	1½/₈	1½/₈	1½/₈	½	7/₁₆ Sq.
2½	2½/₈	1½/₈	2½/₈	2½/₈	½	7/₁₆ Sq.
3½	3½/₈	1½/₈		2½/₈	¾	7/₁₆ Sq.
4½	4½/₈	1½/₈		3½/₈	¾	7/₁₆ Sq.

For 30" Hg. vacuum and 30 psig ranges only

Size	A	B	D (½ conn.)	D (¼ conn.)	E	F
3½	3½/₈	1½/₈		2½/₈	15/₃₂	¾ x ¾
4½	4½/₈	1½/₈		3½/₈	15/₃₂	¾ x ¾



## PLAIN CASE

Drawn steel construction

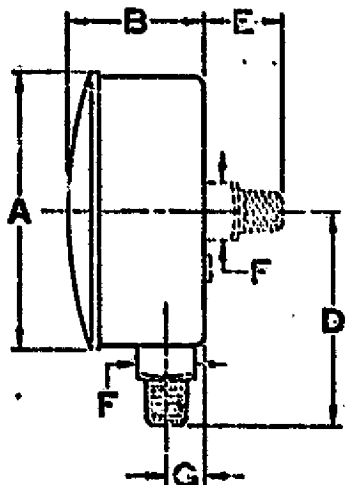
Center back connection—1½", 2", 2½".

Size	A	B	E (½ conn.)	E (¼ conn.)	F
1½	1½/₄	1½/₈	1½/₈	1½/₈	7/₁₆ Sq.
2	2½/₈	1½/₈	2½/₈	2½/₈	7/₁₆ Sq.
2½	2½/₈	1½/₈	2½/₈	2½/₈	7/₁₆ Sq.

## CLEARFRONT PLAIN CASE

Drawn steel construction, bottom or center back connection—1½".

Drawn stainless steel construction, bottom connection—2".

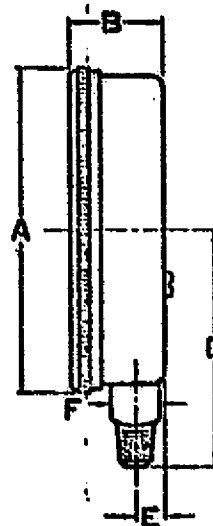


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## BRASS CASE

Drawn brass construction

Bottom connection—2", 2½".



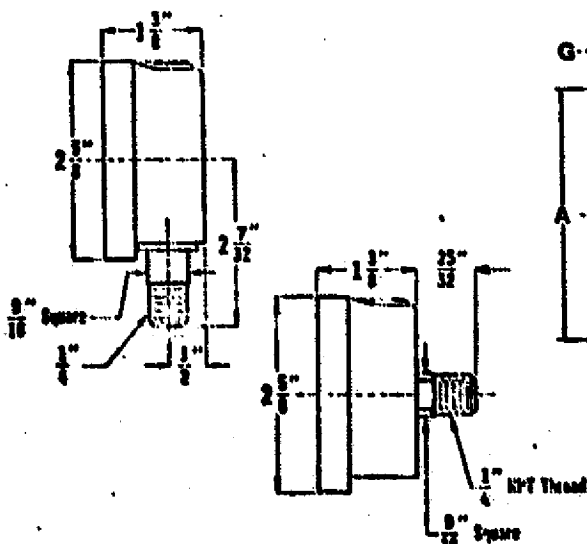
Size	A	B	D	E	F	G	N.P.T. conn.
1½	1½	1¼	1½	1½	7/16 Sq.	¾	¾
2	2½	1¾	1¾	—	7/16 Sq.	¾	¾

Size	A	B	D (¾ conn.)	E	F
2	2½	1¾	1½	1½	7/16 Sq.
2½	2½	1¾	2½	1½	7/16 Sq.

## OIL-FILLED PLAIN CASE

Phenolic construction

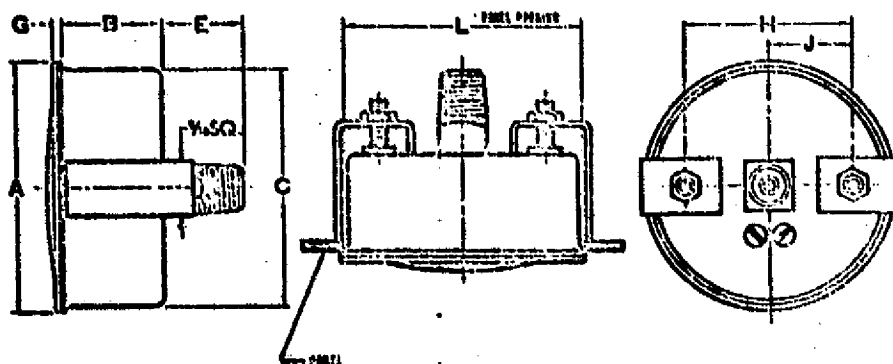
Bottom or center back connection—2½".



## FLUSH CASE

Drawn steel construction

Center back connection—2", 2½", 3½".



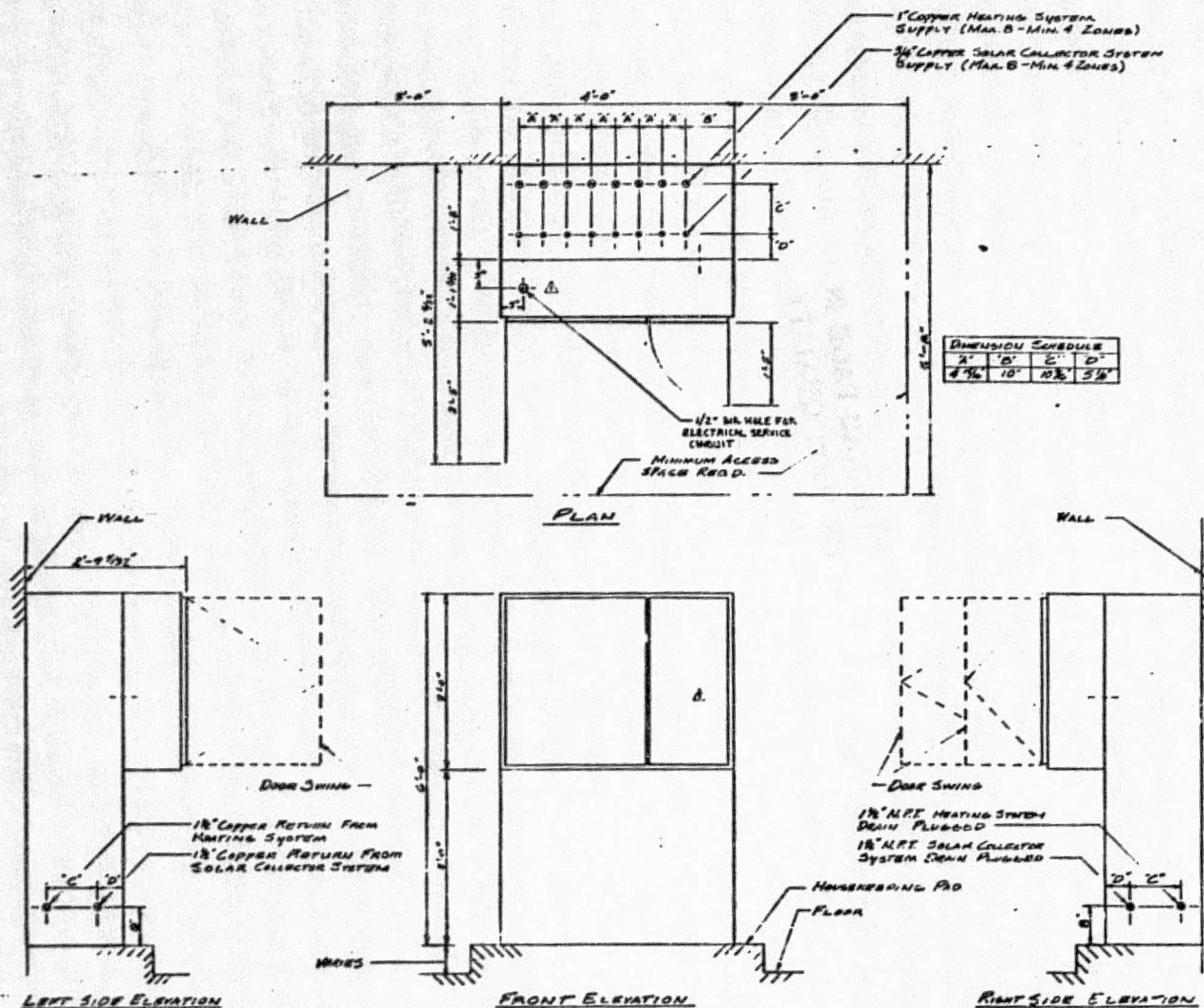
Size	A	B	C	E (¾ conn.)	F (¾ conn.)	G	H	J	L
2	2½	1¾	2½	1½	1½	¾	1½	¾	2½
2½	2½	1¾	2½	1½	1½	¾	2½	1¾	2½
3½	3½	1¾	3½	—	¾	¾	3½	1¾	3½

**APPENDIX F**

**I.P.E.C.H. INSTALLATION DIMENSIONS**

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### INSTALLATION NOTES

- 1 INSTALL PIPING CONNECTIONS WITH BENDS OR OFFSETS TO MINIMIZE EXPANSION FORCE.
- 2 APPROXIMATE OPERATING WEIGHT 900 LB.
- 3 ELECTRICAL DATA: MAX. 2-1/4 HP MOTORS 115-230V, 1 PHASE, 60 HZ.
- 4 PROVIDE FLOOR DRAIN ADJACENT TO IPSEA FOR DRAINING PUMP.

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REV	DATE	DESCRIPTION	BY
1	2-78	CHANGES REC. SERVICE LOCATION	VB
2	2-78	SUPPLIER CONTROL COPY	
3	2-78	P.O. BSA-34	SMITHSONIAN PLANT 5
4	2-78	ANDOVER	MARACONNETTS CO.
5	2-78	1" x 1" 1/2" PHOTO	IN
6	2-78	NATIONAL FIRE FIGHT CENTER NAB-78	
7	2-78	MECHANICAL SUB SYSTEM	
8	2-78	IPSCN INSTALLATION DIMENSIONS	1061-000



## HAZARD ANALYSIS

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## 1.0 Introduction

### 1.1 Scope and Purpose

The hazard analysis contained herein is intended to evaluate the inherent safety of the Integrated Programmable Electronic Controller and Hydronics Package (IPECHP), and to present a qualitative assessment of potential hazards in installation, operation and maintenance of the equipment. The hazard analysis includes identification and categorization of potential hazards, and a description of the design, procedural and maintenance instructions, and documentation used to assure safe operation of the IPECHP.

### 1.2 Background and Approach

The IPECHP, in its normal operational environment, presents no hazards to the occupants of the facility, since the components/subassemblies are located in a locked cabinet in the utility area.

The initial installation on-site is performed by licensed electricians and plumbers, in accordance with approved safety codes. It should also be pointed out that the basic level of complexity and hazard potential of the electrical and hydronics subassemblies is no greater than typical domestic hot-water heating systems, and therefore, presents no challenge to the state-of-the-art.

## 2.0 Safety Criteria

The intent of the operational concepts of the IPECHP is to provide a completely safe controller and hydronics subsystem that can be installed and maintained by suitably trained personnel without any hazards to personnel, equipment, or structure.

## 2.1 Definitions

The definitions given below are derived from MIL-STD-882, "System Safety Program for Systems and Associated Subsystems and Equipment: Requirements for".

Safety. Freedom from those conditions that can cause injury or death to personnel, damage to or loss of equipment or property.

Systems. A composite, at any level of complexity, of operational and support equipment, personnel, facilities, and software which are used together as an entity and are capable of performing and/or supporting an operation role.

Hazard. Any real or potential condition that can cause injury or death to personnel, or damage to or loss of equipment or property.

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## 2.2 Hazard Level Categories

These are qualitative measures of hazards stated in relative terms. MIL-STD-882 established and defines the following categories. The basis is that personnel error, environment, design characteristics, procedural deficiencies, or subsystem/component failure or malfunction:

### a. Category I - Negligible

. . . will not result in personnel injury or system damage

### b. Category II - Marginal

. . . can be counteracted or controlled without injury to personnel or major system damage.

c. Category III - Critical

. . . will cause personnel injury or major damage, or will require immediate corrective action for personnel or system survival.

d. Category IV - Catastrophic

. . . will cause death or sever injury to personnel, or system loss.

3.0 Hazard Analysis

This analysis is presented in the narrative form rather than as a matrix or "hazard tree" because of the preliminary nature of the maintenance approach at this time. The basic design concepts of the IPECHP will assure that no hazards exist to personnel occupying the facility during normal operation of the heating and hot-water system.

3.1 Hazard Identification

The potential hazards associated with the IPECHP can only occur in the event of a malfunction of the protective devices in the electrical and hydrinics subassemblies, or during maintenance activity which requires personnel access to the IPECHP cabinet. These potential hazards would be identified as indicated below.

- a. Personnel - electrical shock, burns, injury due to mechanical malfunctions.
- b. Equipment - damage or loss of function due to the component failure. (Damage would require simultaneous component and protective device failure, in the case of the electrical subassembly.
- c. Structure - damage or loss of function due to major failure/malfunction of a component or subassembly.

### 3.2 Source of Hazards

The possible sources of hazards under abnormal or maintenance conditions are enumerated in the following paragraphs.

#### 3.2.1 Hazards to Personnel

During maintenance, the components which operate directly from the 115 volt AC power source could present a personnel hazard. These are the pump motors, relays, and the 115 volt/24 volt step-down transformers.

The piping and heat exchanger associated with the hydronics subsystem internal to the IPECHP could reach a maximum temperature of 240°F, which could result in severe burns. Additionally, the piping could burst if external pressure regulating/safety controls were to malfunction.

Mechanical hazards to personnel would be sharp edges on cabinets, brackets, or the Controller Assembly enclosure, or heavy subassemblies that are not provided with handles or other suitable gripping means so that they could be inadvertently dropped during maintenance actions.

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#### 3.2.2 Hazards to Equipment

Under abnormal conditions which could result from failure of protective devices to operate, the IPECHP could suffer wiring damage or burst pipes or leaking couplings/fittings in the hydronics subassembly.

#### 3.2.3 Hazards to Structure

The cabinet containing the IPECHP subassemblies could suffer permanent damage under highly abnormal conditions (i.e. component damage). However, because of its construction and the fact that it is

closed and locked during normal operation, there will be no damage to the facility caused by failure of the IPECHP in the extreme and very remote possibility of fire or explosion. Since the materials in the IPECHP are non-flammable and no volatile fluids are used in the system, the cause of a fire or explosion have to come from some malfunction or environmental anomaly external to the IPECHP.

### 3.3 Level of Hazards

#### 3.3.1 Severity of Personnel Hazards

Electrical shock to maintenance personnel could be a critical to catastrophic hazard, depending on conditions of skin resistance, etc. Similarly burns from the hydronics components/assemblies could be minor or major (marginal to critical) depending on the temperature of the part, and whether protective coverings had been removed for inspection purposes.

#### 3.3.2 Severity of Hazards to Equipment

Wiring damage and/or burst pipes/fittings could result in system loss, and therefore are categorized as critical to catastrophic (major).

#### 3.3.3 Severity of Hazards to Structure

Fire damage to the IPECHP cabinet could be classified as critical to catastrophic, depending on the number of components involved. Water damage from burst pipes would be considered negligible or marginal.

### 3.4 Elimination or Control of Hazards

#### 3.4.1 Control of Hazards to Personnel

##### 3.4.1.1 Manufacturing

All internal wiring is connected, inspected and tested by SKC personnel prior to shipment to the installation point. UL listed motors, relays, wiring and other associated parts connected to the 120 volt powerline will be used. The completed IPECHP assembly will be tested for dielectric withstanding voltage ("hipot") capability, and leakage current, in compliance with UL standards. All of the plumbing in the hydronics package is connected, inspected and tested (at 1.5 times the operating pressure) by a licensed steamfitter at SKC prior to shipment.

Areas within the cabinet where voltages in excess of 30 volts AC (r.m.s.) are used are identified with high-voltage warning labels, and are suitably covered to prevent accidental contact by personnel. Similarly, the hydronics subassembly piping is covered with insulation and identified by high temperature warning labels.

A plastic shield is used to isolate the hydronics subassembly, located on the frame of the cabinet, from the controller subassembly, located on the door of the cabinet. All mechanical parts and enclosures have rounded corners and the edges of brackets are rounded to avoid personnel injury.

There is no overpressurization protection within the IPECHP unit. However, the external heating system piping must be designed to include suitable automatic pressure-relief valves, and manual control valves will be required at the input to the IPECHP for use by maintenance personnel.

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#### 3.4.1.2 Installation

Hydronic and electrical connections to the IPECHP unit on-site must be made by licensed personnel in accordance with local building codes and the National Electric Code. Part of the installation instructions call for assuring that the "green wire ground" makes a good connection to the electrical ground of the facility. A ground stud on the cabinet is used for this purpose, in addition to the third wire in the power cable.

#### 3.4.1.3 Maintenance

Maintenance operations will be performed by trained personnel who are familiar with safety requirements associated with 120 volt AC power and pressurized hydraulic systems. In addition, the instruction manuals will include clearly emphasized warnings whenever a potentially hazardous maintenance action is undertaken. Normally, after any required tests are performed to isolate the faulty component, all voltage to the unit will be disconnected at the facility electrical control box before the maintenance action is continued.

#### 3.4.2 Control of Hazards to Equipment

##### 3.4.2.1 Manufacturing

The electrical components are protected from potential damage by the cabinet circuit breaker and individual branch fuses for each major subassembly. The component insulation is designed to be flame retardant and non-combustible. The hydronic subassembly could use a number of fluids, but is mainly intended for use with ordinary water, so that no toxic or flammable fluids will be present.

##### 3.4.2.2 Installation

Comments are similar to personnel safety during installation. All operations will be performed by licensed personnel using



the same skills required for connection of ordinary domestic heating and hot-water systems.

#### 3.4.2.3 Maintenance

Potential hazards to equipment during maintenance activities will be controlled by the inherent design provisions. Wiring harness will allow removal of electrical parts and assemblies, such as relays, motors, or the Controller Assembly without damage or the necessity of awkward positioning of heavy parts. The hydronics assembly is similarly designed such that on-site maintenance will not damage the equipment, provided that normal care is exercised.

#### 3.4.3 Control of Hazards to Structure

Hazards to the IPECHP structure are controlled by the same precautions as apply to equipment hazards for the manufacturing, installation, and maintenance phases. The likelihood that a component failure would also involve failure of a fuse and circuit breaker (in series) to open the electrical circuit is so remote as to be considered impossible.

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#### 4.0 Residual Hazards

The only residual hazard potential in the present design of the IPECHP is associated with overpressure in the hydronics assembly during a maintenance action. However, it is expected that there will be a pressure indicator and manual shutoff valves readily accessible to the maintenance person in the event that the external automatic pressure-relief system is not functioning properly.

5.1 Electrical Failures

The only electrical failure modes, at the component level, that could create a hazard would be partial short circuits in the cabinet circuit breaker series leg, a fuse (next to impossible) and an electrical part, so that excessive current would flow, causing melting of wire insulation. The current would have to be low enough so that the fuse or circuit breaker in the branch circuit of the main facility electrical box does not blow, and yet high enough to raise the temperature of the wire to the insulation melting point. Again, this — even independently of the failure of the protective devices in the IPECHP to operate — is an extremely remote, if not impossible, condition.

5.2 Hydronics Failure

Failure of the piping or connections in the hydronics assembly would involve cracking or rupture of the piping and/or connection. The materials and processes used are rated at pressures over 10 times higher than the 60 p.s.i. used in this system, so that the likelihood of a major hazard is extremely remote.

6.0 Safety Documentation

A safety file will be set up and maintained throughout the duration of the program. It will contain copies of all proof testing of electrical and hydronic assemblies, records of inspections by follow-up services of Underwriters Laboratories and fire inspection personnel, and any safety reports that might be obtained from field experience, together with corrective action taken.